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PROCEEDINGS OF THE 1980 NORTH AMERICAN EEL CONFERENCE

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PROCEEDINGS OF THE 1980 NORTH AMERICAN EEL CONFERENCE

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PREFACE

The publication of the *Proceedings of the 1980 North American Eel Conference* is a special issue of the Ontario Fisheries Technical Report Series. Due to the multi-paper content of this publication, it has been necessary to modify the format of this report from the standards established for the series.

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ODE TO ANGUILLA

There once was an elver named Sam,
Who decided to climb Cornwall Dam.
He squiggled and squirmed, under willows he wormed,
'Til he reached the top and abruptly was stopped,
Doused in a bucket of 222,
He was tagged in the jaw by Peter Liew.

Then off like a dog with a can on his tail,
He headed upstream 'til he found a large nail.
Then off with a twist, came the tag from his lip,
And on up the river he proceeded to slip.

It was hard to eat with a jaw split in two,
But when you're an eel, you have to make do.
Insects and fish added length to his frame,
Developing gonads forced a change in his name!!

Samantha continued to grow leaps and bounds,
'Til universal yearnings turned her around.
She headed downstream, one thing on her mind,
And found herself in a terrible bind.
In the blades of the turbine, I may breathe my last,
So I'll go through the locks to save my ass!!

Down Lake St. Francis, she twirls and she dances,
Past Montreal with no backward glances.
A Québec elle ira comme il pourra,
Pour chercher un homme comme il ne s'en trouve pas.

In their search for a mate, the girls became frantic,
So they headed on out to the North Atlantic.
At Prince Edward Island, they all hung a right,
And the next thing we knew, they were right out of sight!

Of their mating behaviour we can scarce speculate,
'Cause nobody knows how eels copulate!!!!

Editor's Note:

The above was prepared during the course of the meeting, as a tribute to Dr. Vladykov, by an international group of meeting attendees who were impressed by the presence and knowledge of Canada's senior authority on eels.

INTRODUCTION TO THE PROCEEDINGS OF THE 1980 NORTH AMERICAN EEL CONFERENCE

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INTRODUCTION

BACKGROUND

A conference to consider various aspects of management and research of the American eel (*Anguilla rostrata*), in North America, was arranged by the Ontario Ministry of Natural Resources with joint sponsorship by the Great Lakes Fishery Commission. The meeting was held at Toronto, Ontario,on February 5, 6 and 7, 1980.

Management and research presentations were given by provincial, state and federal agency representatives from eastern North America. Visiting experts from Holland and Ireland presented papers on the European eel situation from both the management and research points of view.

REASON FOR THE CONFERENCE AND GENERAL OBJECTIVES

The Ontario Ministry of Natural Resources, which is responsible for managing fisheries in the Canadian waters of the Great Lakes, has been concerned for some time with the substantial increase in the harvesting of eels from Lake Ontario. The recent interest in fishing eels in Ontario waters is directly related to the high price and demand for eels on the European market. The questions of management, research and other subjects related to eels was dealt with in correspondence circulated by the Ministry to Canadian and United States fishery agencies prior to the Conference.

The following are quotes from Ministry correspondence:

(From February 2, 1979 letter):

"The Ontario Ministry of Natural Resources is charged with the responsibility of managing American eel (*Anguilla rostrata*) stocks in Lake Ontario. However, Lake Ontario is only a small part of a much larger aquatic system where the American eel completes its life cycle. Attempts to manage one aspect of this system could be futile unless other components are approached in a similar fashion.

The decline in the abundance of the European eel[1] (*Anguilla anguilla*) and substantial increase in harvest of American eels from Lake Ontario have recently caused concern. It is because of this concern that we are writing today to determine what interest there may be in North America for an American Eel Management Conference.

The objectives of such a conference would be;

(a) To exchange information on the biological and socio-economic aspects of the eel population and its harvest;

(b) To outline problems and concerns of the various jurisdictions relating to the management of eels;

(c) To ascertain the causes of the European eel decline;[1]

(d) To develop a coordinated approach for the management of the North American eel population."

(From Ontario Ministry of Natural Resources August 2, 1979 letter):

"It is our intention to arrange for the attendance of an appropriate expert from Europe, who can review for the meeting the European eel fishery past and present. We are hopeful that discussion generated by this presentation and comments on North American situations will lead to many useful points which will ultimately assist with the development of a framework for the coordinated approach for the management of eel stocks in eastern North America.

In summary, I can say that response to the proposal of an eel conference has been enthusiastic. Plans are proceeding to hold the meeting at Toronto in February, 1980. We hope to have a number of agency reports for presentation at the meeting and plans are being made to have a specialist from Europe review the management of their eel fisheries for the meeting."

SUMMARY

All objectives were addressed during the presentation and discussion of reports from many areas of North America and Europe. The majority of North American participants who admitted to arriving at the meeting with a limited knowledge of eel management and research, left with an insight into "global eel problems" and a better appreciation of their own situations.

Conference presentations and discussions were taped and rapporteurs prepared summary notes on question and answer sessions.

The resulting report contains copies of available written presentations, abstracts of other papers and relevant discussions of the proceedings. This collection of Conference material is intended to provide attendees with a useful record of the meeting. For others interested in the subject, it will provide a valuable reference to the 1980 American Eel Conference.

---

[1]It was stated by Dr. C. L. Deelder during the Conference that European eel stocks have not declined (see "Some Conference Highlights").

SOME CONFERENCE HIGHLIGHTS

GENERAL

Commercial fishermen in the northeastern United States and southeastern Canada have fished eels for more than 100 years.

Today, we know relatively little about North American eel stocks, in spite of the fact that active studies have been conducted for more than a quarter of a century.

Although American eels are present in fresh waters of the southeastern United States (Georgia, Florida, etc.), they appear to be of little or no interest to commercial fishermen in that region and of minor interest to fishermen of the mid-Atlantic states.

SPECIFIC

There was a feeling among some Conference delegates from Europe and North America that "all" silver eels should be harvested.

The question of whether or not eels tend to "home", i.e. return to the river system where their parents grew to adulthood, is apparently not resolved. Dr. C. L. Deelder indicated that there is no "homing". Initially Dr. C. Moriarty agreed, but appeared to have some doubts.

There was a feeling among some contributors that harvesting elvers was not harmful, provided there was suitable control. Other speakers were opposed to the harvesting of elvers, particularly massive elver harvesting for export purposes.

The increase in the demand for North American eels by the European market was not brought about by a decline in stocks of European eels. Rather, it appears to be due to a greatly increased total demand for eels by the European market, which cannot be totally satisfied by European fisheries.

Dr. C. L. Deelder reviewed the successful eel culture operations in southern Europe (particularly in Italy). He indicated that the high quality and considerable quantity of eels being produced in culture operations could create a real problem for commercial eel fisheries in Europe and North America.

Dr. J. J. Poluhowich spoke on the eel information centre being established at the University of Bridgeport (Conn.).

SUMMARY OF CONCLUSIONS

The majority of meeting delegates felt there was no need for an inter-regional approach to the management of eel stocks. Because of the nature of eel fisheries, it was considered by some that management could be handled best on a local fishery basis.

Meeting delegates agreed that there is a need to establish a North American eel working group or committee that could meet every year or two, and that it should maintain contact with the (ICES/EIFAC)[2] European Eel Working Group, chaired by Dr. C. L. Deelder.

CONFERENCE SECRETARIAT

E. W. (Ted) Burridge (OMNR)
Mrs. Jay Hendry (OMNR)
Mike Eckersley (OMNR)
Miss Marg Ross (GLFC)
Mrs. Pat MacDonald (OMNR)

AGENCY ABBREVIATIONS

FEDERAL

DFO - Department of Fisheries and Oceans

PROVINCIAL

OMNR - Ontario Ministry of Natural Resources
QMSFG - Quebec Ministry of Sport Fisheries and Game
QMAFF - Quebec Ministry of Agriculture, Fisheries and Food
PEIDF - Prince Edward Island Department of Fisheries
NDF - Newfoundland Department of Fisheries
PNBF - Province of New Brunswick Fisheries
NSDF - Nova Scotia Department of Fisheries

STATE

NYDEC - New York Department of Environmental Conservation
MDMF - Massachusetts Division of Marine Fisheries
MDMR - Maine Department of Marine Resources
NCWRC - North Carolina Wildlife Resource Commission
GDNR - Georgia Department of Natural Resources

INTERNATIONAL

GLFC - Great Lakes Fishery Commission

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[2]International Council for the Exploration of the Sea/European Inland Fisheries Advisory Commission.

MINISTER'S WELCOME

The Conference was opened by The Honourable James A. C. Auld, Minister of Natural Resources for the Province of Ontario, who welcomed delegates to the Conference and indicated that the meetings were being sponsored jointly by the Ontario Ministry of Natural Resources and the Great Lakes Fishery Commission. He recapped briefly the history of the eel fishery in Lake Ontario, pointing out its increasing importance to fishermen since the 1960's. Mr. Auld concluded his remarks by thanking the representatives for attending the American Eel Conference.

CHAIRMAN'S REMARKS

The official Conference Chairman, Mr. K. H. Loftus, after thanking the Minister for his remarks, indicated that he would be unable to attend the entire conference. He expressed great pleasure at being able to leave the meeting in the hands of the Ministry's senior fisheries research officer, Mr. A. H. Lawrie.

In his opening remarks, Mr. Loftus explained that in recent years, the Ministry and the Great Lakes Fishery Commission have jointly sponsored a number of symposia similar to the Eel Conference. He pointed out the value, to the advancement of fisheries and ecological sciences. that this type of meeting provides. Mr. Loftus reviewed these conferences, starting with the SCOL Symposium which dealt with the impact of stress on salmonid communities in oligotrophic lakes. SCOL was followed by PERCIS which was an attempt to achieve the same kind of perspective on percid communities. The Sea Lamprey International Symposium (SLIS) was held recently and dealt with the sea lamprey situation in the Great Lakes. The next in the series (September/October, 1980) will be the STOCS Symposium.

In his concluding remarks, the Chairman introduced two special overseas guests, Dr. C. L. Deelder and Dr. C. Moriarty. He thanked them for taking the time to attend the American Eel Conference and for their offer to share their many years of eel-related scientific information with the meeting delegates.

FEDERAL, PROVINCIAL & STATE AGENCY REPORTS

ONTARIO

OPERATION OF THE EEL LADDER AT THE MOSES-SAUNDERS GENERATING STATION, CORNWALL 1974-1979

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ABSTRACT

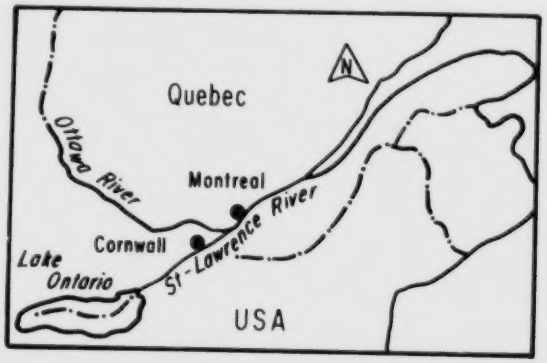
To facilitate the movement of American eels (*Anguilla rostrata*) migrating up the St. Lawrence River, an eel ladder was constructed at the Moses-Saunders Power Dam, Cornwall, Ontario,in 1974. The wooden structure worked effectively between 1974 and 1979, moving approximately 4.4 million eels over the dam. The ladder has provided the opportunity to assess some biological characteristics of the migrating population. It also has allowed the evolution of a fishway which is capable of effectively passing eels. Expansion of the biological data collection program and replacement of the current ladder with a permanent structure are two major programs planned for the near future.

INTRODUCTION

Prior to the construction of the St. Lawrence Seaway from 1954-1958, the American eel (*Anguilla rostrata*) migration up the St. Lawrence River was unimpeded from Valleyfield, Quebec,to Lake Ontario. The construction activities and the resultant locks and dams are thought to have reduced the number of eels reaching Lake Ontario (Kolenosky and Hendry 1982). In 1974, an experimental eel ladder was constructed at the Moses-Saunders Power Dam at Cornwall, Ontario (Figure 1), to increase the number of eels passing upstream and to help alleviate the clogging of power generation equipment during dewatering operations. The increased passage of eels was expected to increase the stock(s) available to the commercial fishery in Lake Ontario (Whitfield and Kolenosky 1978).

This paper summarizes the information available on the eel ladder modifications and generally describes the operation of the ladder from 1974 to 1979.

Specific information on the ladder design, operation and biological implications is provided in a number of previous reports. Whitfield and Kolenosky (1978) report on the design and operation of the ladder from 1974 to 1977. Liew (1975, 1976, 1977, 1978, 1982) and Vladykov, Liew and Whitfield (1975) provide specific operating details and report on the tagging program, the collection of basic biological information and the various modifications made in the design and operation of the ladder from 1974 to 1978. Martel (1979) details the 1979 operation and Kolenosky and Hendry (1982) report on the impact of the ladder on the commercial fishery in Lake Ontario. Kolenosky (1976) describes the potential for mortality of adult eels passing downstream through the turbines of the generating station.



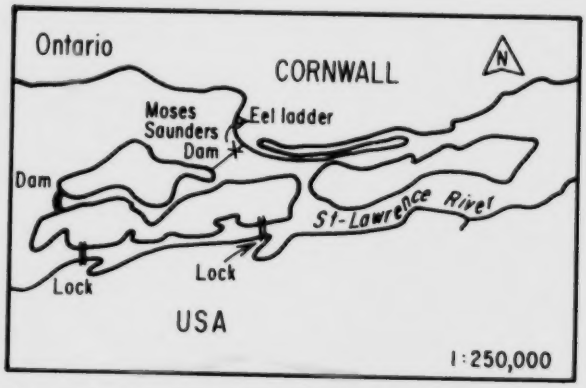


Figure 1. Location of the Eel Ladder. (Drawn by M. C. Belzile).

LADDER DESIGN

The ladder is situated in the most northerly ice sluice of the Moses-Saunders Dam, immediately adjacent to the north shore of the St. Lawrence River at Cornwall, Ontario (Figure 1). The present ladder consists of a three-sided wooden trough which criss-crosses the face of the ice sluice 8.5 times in a vertical lift of 29.3 m (Figures 2, 3). There are level boxes at the end of each traverse to provide temporary

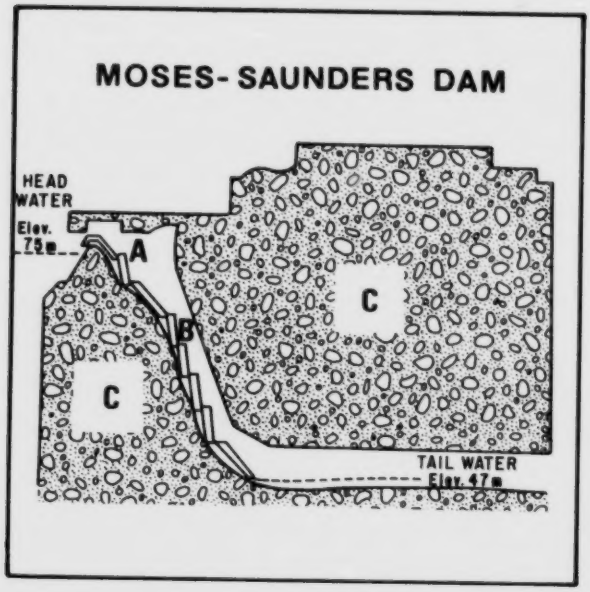


Figure 2. Cross-sectional view of the ice chute and eel ladder showing the ladder traverses (A), the ice sluice (B) and the dam structure (C).
(From Whitfield and Kolenosky 1978)

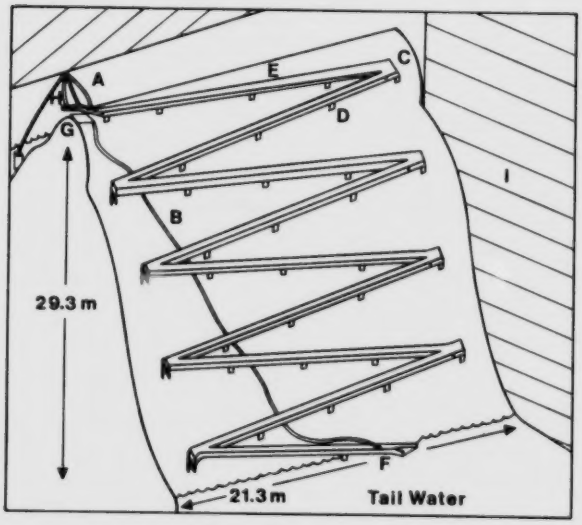


Figure 3. A cutaway view of the eel ladder showing the hose feeding the ladder (A), the attractant hose for the bottom of the ladder (B), a resting box (C), a support bracket (D), a trough (E), the tailwater funnel (F), the ice gate (G), the attractant hose at the top of the ladder (H) and the sidewall of the ice sluice (I).
(Drawn by M. C. Belzile).

resting areas for eels during their climb. Angled wooden baffles and synthetic vegetation are fastened to the bottom of the trough to control the water velocity down the ladder and to provide a substrate which facilitates the upward movement of eels. The ladder slope is 12° and the total ladder length is 156 m. A pumping system provides water for the ladder from the headpond as well as an attractant current at the base of the ladder. Water in the trough has a depth of from 1.5 cm to 5.0 cm and a velocity of approximately 15.3 m/min. The discharge is estimated at 113 L/min.

MODIFICATIONS

The present ladder is similar to the original structure built in 1974. Minor modifications are the result of practical experimentation designed to increase the number of eels using the ladder and to reduce the operating costs and logistical problems.

The fresh willow cuttings originally used in the trough were replaced with synthetic vegetation (trade name "Cassonia"). Tests using the eel movement rate as a criterion indicated there was no significant difference between the two media (Liew 1977). The willow had to be replaced weekly while installation and removal of the synthetic material is done only once a year. In the interest of cost reduction, the synthetic now is used exclusively.

The slope of the ladder was varied up to a maximum of 20° during 1975 to determine the optimal slope for eel movement. Using the criterion of eel movement rate, a slope of 12° was determined to be flat enough not to inhibit movement, and steep enough to ensure that an adequate water depth and current were maintained in all sections of the ladder. The adjustment to 12° required adding one more traverse to the ladder, bringing the total number of traverses to 8.5. This slope appears optimal given the trough design, construction material and water supply used.

A number of minor design modifications were made to enhance eel movement (Liew 1975). The entrance chute was extended further into the water and reconstructed to a funnel shape to promote access to the ladder. A resting box was added at the first turn, to reduce the number of eels swept back into the tailwater, and a resting box at the exit chute was replaced with a straight trough, to eliminate blockages at this point. The ladder was in shadow over most of its ascent, with the exception of the top two troughs. Subsequently, a canvas cover was placed over the grating on the dam above. This reduced the incident light levels on the upper troughs and resulted in an increased eel movement rate.

There were several factors which acted separately or concurrently to temporarily slow

Table 1. General operation of the eel ladder: 1974-1979.

Year[a]	Days of Operation	Start / Finish Date	Date of Peak Run	Water Temperature(°C) Start	Peak	Finish	No. Eels[b] At Peak (24hrs.)	Total No.[c] Eels passed
1974	27	Aug. 15 / Sept. 11	-	-	-	-	-	130,000
1975	88	June 19 / Sept. 14	July 17	18.9	23.0	18.5	19,784	936,000
1976	98	June 15 / Sept. 20	July 21	15.5	22.0	17.0	10,200	659,000
1977	107	June 29 / Oct. 13	Aug. 15	14.0	22.0	12.0	-	997,000
1978	90	July 6 / Oct. 2	July 27	16.0	21.0	14.0	-	795,000
1979	92	July 11 / Oct. 9	Aug. 9	17.2	22.5	14.6	21,643	864,000
Total								4,381,000

a. 1974 was the initial year of operation and the short operation period reflects this.

b. Eels counted in 15 min. intervals, several times/day then extrapolated to give a 24 hr. (daily) count.

c. Count extrapolated from daily counts.

or halt the run. These included reduced water temperatures, increases in natural light levels in the ice sluice, extended human disturbance of the eels in the troughs and reductions in the flow rate of the water through the generating station (Liew 1977). Of these, only extended periods of cool water temperature significantly affected the run. This factor was probably responsible for the small size of the run in 1976 (Table 1).

GENERAL OPERATION

Table 1 provides the general operational data for 1974, when the ladder was partially operational, and for the period between 1975 and 1979, when the ladder was fully operational.

Several generalizations can be made concerning the use of the ladder. The initiation and cessation of the run are dependent, to some degree, on the water temperature (Liew 1976). Temperatures between 14.0°C and 18.9°C have been recorded at run initiation and the run has ceased at temperatures between 18.5°C and 12.0°C. The peak eel movement occurs at temperatures between 21.0°C and 23.0°C. With respect to the length distribution of eels using the ladder, there seems to be a subjective correlation between the length of eels and water temperature. As the water temperature declined, the percentage of smaller eels passing over the ladder decreased (Liew 1976, 1977). The minimum time for an eel to climb the ladder has been estimated at 70 minutes (Liew 1975).

Of 2333 fish sampled in 1974, 1975 and 1976, all were female except for 212 fish which were not developed sufficiently to sex effectively (Liew 1975, 1976; Vladykov et al. 1975). A limited stomach contents analysis done during the summers of 1974 (Vladykov et al. 1975) and 1975 (Liew 1975) indicated that only 12 of 425 fish had been feeding immediately before being captured. All 12 samples consisted of Diptera (Liew 1975).

In an attempt to determine the movement, mortality rates and contribution to the commercial fishery, a tagging program was instituted between 1975 and 1978. Of the 36,539 fish tagged with split-ring jaw tags, 35,550 were released upstream (Liew 1975, 1977, 1978, 1979). A total of 23 tags have been recovered to date.

The return rate is too low to assess the distribution of eels upstream of the ladder, although the majority of the fish have been recovered between the ladder and the eastern portion of Lake Ontario. Nevertheless, one fish tagged in 1975 was recaptured in the Niagara River in 1977, an upstream distance of over 400 km. Another fish, released below the dam, was recaptured two years later 250 km downstream. Only one fish was recaptured the same year it was tagged. It had moved 225 km upstream in 53 days, an average migrating speed of 4.25 km per day (Liew 1978).

The number of tag returns to date has been negligible. This may be due to a combination of factors including tag loss, tag-induced mortality, poor returns by fishermen and the fact that many

of the tagged fish have probably not entered the Lake Ontario commercial fishery yet, the only potential major source of samples. No data are currently available to definitively assess the relative importance of these factors.

Age frequencies generated from otolith analyses in 1974 and 1975 indicate the eels ranged from 5-16 years old (mean age 9) in 1974 and from 2-11 years old (mean age 6) in 1975 (Liew 1976). The length frequencies vary from year to year due to a number of factors (Liew 1976). Those sampled from 1974 to 1979 ranged from 13.0 cm to 84.0 cm in total length with most falling in the 25.0 cm to 45.0 cm range. Weights ranged from 1.0 g to 1,140.0 g with the majority between 20 g and 125 g (Liew 1976). Liew (1975, 1976, 1977, 1978, 1979, 1982) provides a more comprehensive review of the tagging program and data on the age, length, weight, condition and growth characteristics of the eels using the ladder.

OUTLOOK

There are two major programs planned for initiation in 1980-1981 at the eel ladder. The performance of the ladder has been satisfactory in moving eels upstream (4.4×10^6 eels between 1974 and 1979). Nevertheless, the current ladder, designed initially as a temporary structure, is now subject to an increasing number of structural problems. As a result, planning is underway to design a replacement ladder. This new ladder will incorporate the modifications made on the old ladder, will be permanent in nature and virtually maintenance-free. The new structure will be capable of annually delivering about twice the number of eels currently passed.

The results of the tagging program have been insufficient for assessing the contribution and, hence, the importance of the ladder to the Lake Ontario commercial fishery. To improve the management data-set, a major tagging program is planned for initiation in 1980. The coded-wire microtagging system will be used with an annual tagging target of 80,000-100,000 fish by 1981. Recapture information will be obtained by sampling the Lake Ontario commercial catch.

SUMMARY

This paper has pointed out the general operating scheme and ladder design, as well as highlighting the general types of biological data collected from 1974-1979. For more detailed descriptions of the operation and the data collected, the reader is referred to the more comprehensive papers listed in the References.

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THE CANADIAN LAKE ONTARIO FISHERY FOR AMERICAN EEL (*Anguilla rostrata*)

by

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ABSTRACT

Lake Ontario represents the furthest migration into fresh water of commercial quantities of American eel (*Anguilla rostrata*). In response to rising prices, historic eel harvest levels of 70 metric tonnes have risen dramatically in the last five years to 215 metric tonnes. Commercial catch sampling data and harvest statistics are examined to determine the impact of this harvest level and the Cornwall eel ladder on the eel population. The decline in the average size of eels in the commercial catch is attributed to both the harvesting of larger eels by the fishery and the contribution of smaller ones by the eel ladder. Despite an influx of additional eels, the catch per unit effort for various gears has been declining. Recent information suggests that a partial blockage of the St. Lawrence River occurred during the construction of the St. Lawrence Seaway. An experimental quota of 270 metric tonnes is planned for 1980 until the full impact of the eel ladder can be assessed.

INTRODUCTION

Lake Ontario is the lowermost of the five Great Lakes and represents the upper limit of commercial quantities of American eel (*Anguilla rostrata*) migrating into fresh water via the St. Lawrence River system. The Province of Ontario has jurisdiction over the northern half of the lake, which has a total area of 19,477 square kilometres (7,518 sq. mi.) and a mean depth of 80 metres (264 ft.) (Ryder 1972). The American eel fishery is concentrated in three statistical districts (Figure 1) at the shallower eastern end of the lake: SD3, SD4 and SD6.

Statistical district 6 accounts for 50-60% of the harvest and thus will be receiving the most attention in this paper. Statistical districts 3 and 4 each make up 20% of the catch (Table 1).

Three types of gear are used to take the bulk of the eel harvest - setlines, hoopnets and trapnets (Table 2). Setlines account for 65% of the catch and are the most popular gear because they require minimal capital investment and can be operated by one individual in nearshore areas. A total of 46 setline licences

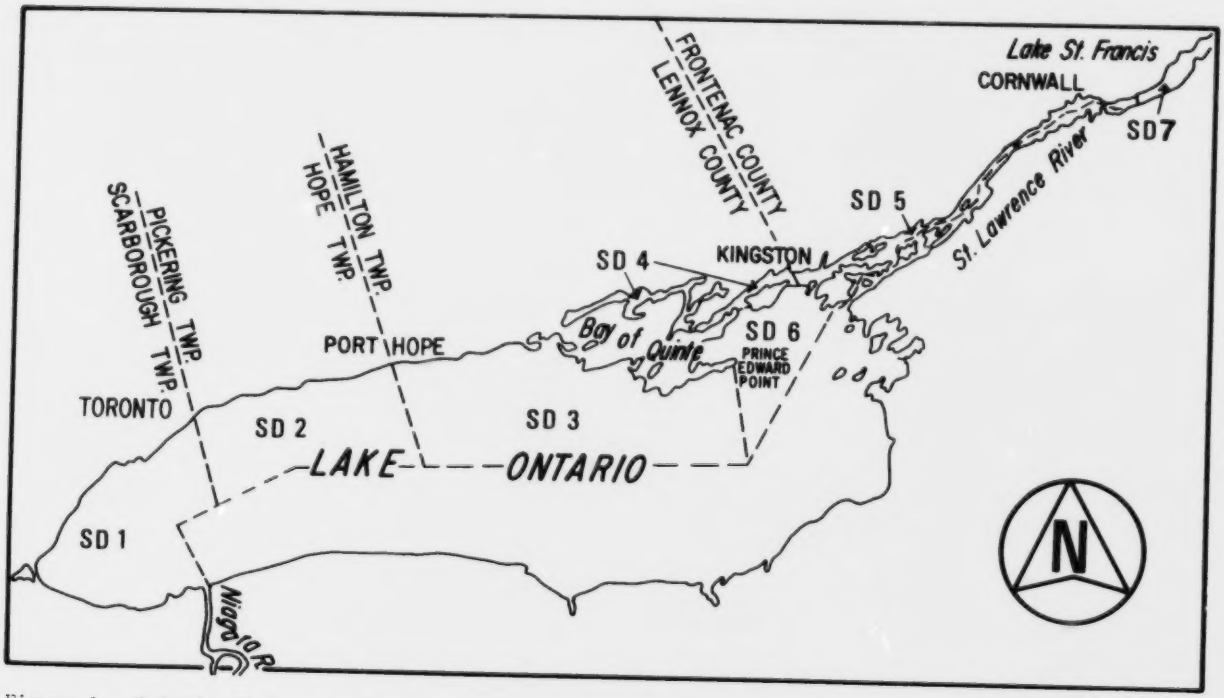

Figure 1. Ontario Ministry of Natural Resources statistical districts of Lake Ontario and the St. Lawrence River.

Table 1. Total annual catch in kilograms of eels for each statistical district of Lake Ontario 1959-1979.

Year	SD 1 Western	SD 2 West Central	SD 3[a] East Central	SD 4 Bay of Quinte	SD 5 Upper St. Lawrence	SD 6[a] East Basin	Total	$/kg
1959	1695.9	285.8	-	20756.4	3303.5	29795.1	55836.7	.06
1960	1590.8	241.3	-	18973.8	5780.6	23461.6	50048.1	.05
1961	129.3	0.5	-	24761.2	5766.1	28438.4	59095.5	.05
1962	73.9	210.9	-	19958.9	4989.1	23987.8	49220.6	.05
1963	14.9	85.7	-	30405.2	9027.4	37283.0	76816.2	.09
1964	-	104.3	21037.2	43404.3	11320.8	32544.4	108411.0	
1965	-	-	23457.9	27332.1	4684.3	22913.7	78388.0	
1966	-	-	16719.9	21400.0	3940.8	17460.1	59520.8	
1967	-	19.5	16220.5	17730.5	6397.5	18495.2	58863.2	.12
1968	-	-	20887.9	28871.6	7539.6	21133.8	78432.9	.11
1969	-	-	14860.1	33774.0	5729.8	22253.2	76617.1	.11
1970	-	-	9649.7	31010.8	8789.3	16699.9	66149.7	.11
1971	-	86.2	7462.9	26536.5	5827.3	36314.6	76227.5	.11
1972	-	-	15194.4	29182.8	4707.8	72699.1	121784.1	
1973	68.5	45.4	9324.5	30452.8	5615.9	39910.7	85417.8	.12
1974	-	33.1	14747.7	30036.9	3677.3	70307.7	118802.7	
1975	47.2	45.8	40085.8	36536.9	9559.9	76862.1	163137.7	.24
1976	-	-	34860.8	32777.0	5235.4	71715.7	144588.9	.21
1977	-	-	52810.9	32118.4	7277.4	81672.5	173879.2	.17
1978	-	-	38036.4	42764.7	9937.8	**131201.1**	221940.0	.41
1979	-	144.2	38538.1	46789.9	18862.2	**106846.9**	211181.3	.62

[a]SD 3 included with SD 6 from 1959 to 1963.

Table 2. Percent of eel harvest taken by major gear types in the Lake Ontario fishery from 1959-1979.

Year	Setline	Hoopnet	Trapnet	Seine	Other
1959	48.6	31.9	-	19.4	0.1
1960	62.7	31.0	-	6.3	-
1961	66.2	24.8	-	9.0	-
1962	72.9	24.7	-	2.3	0.1
1963	70.8	20.5	-	8.4	0.3
1964	80.4	17.4	0.1	2.1	-
1965	68.3	23.4	2.1	6.2	-
1966	56.1	32.5	7.1	4.3	-
1967	53.6	34.2	8.0	3.2	1.0
1968	45.9	41.6	10.6	1.8	0.1
1969	59.5	28.7	10.9	0.7	0.2
1970	54.0	32.3	12.3	1.0	0.4
1971	48.2	30.2	16.6	4.7	0.3
1972	66.5	12.7	13.7	7.1	-
1973	58.6	22.7	10.3	1.4	7.0
1974	60.7	19.5	15.8	2.4	1.6
1975	62.7	19.3	11.8	3.7	2.5
1976	70.4	13.8	15.1	0.1	0.6
1977	66.6	15.5	11.9	6.0	-
1978	73.0	11.0	10.0	6.0	-
1979	71.0	15.0	9.0	4.0	1.0

have been issued for eastern Lake Ontario. The lines range in size from 150 to 600 hooks each. The hooks are baited with worms or cut fish and the lines are run once or twice a day, depending on weather and eel availability. During peek eel activity, the lines may be run continuously with fishermen removing eels and rebaiting the hooks as they go. On an average line of 300 hooks, a daily catch of eels would average 45 kilograms (100 lbs.). The setline fishing season lasts from May to September with peak harvests occurring in June.

The other two types of gear are basic impounding or live-capture devices which catch a variety of species. Hoopnets are used primarily in the spring and fall in the Bay of Quinte (SD 4) while trapnets are used throughout the summer in the small bays of the open lake. There are 44 hoopnet and 13 trapnet licences in eastern Lake Ontario and they take 20% and 15% of the harvest respectively. A small quantity of eels also is taken with seine nets.

THE EEL HARVEST

During the past five years, the eel harvest has increased dramatically in response to rising prices. Licenced effort has been maximized over the past two years, producing reported catches as high as 222 metric tonnes (489,000 lbs) (Table 1). American eels are now the most valuable fish in the Lake Ontario fishery and represent the largest poundage of any species caught. There are five registered processing plants which receive this harvest for export to Europe and Asia. Because of high contaminant levels, Lake Ontario eels are not saleable in North America and only can be exported to countries which accept these contaminant levels.

The recent increase in the value of eels has resulted in numerous requests from fishermen for new licences or additional gear for existing licences. The Ministry has been concerned about the ability of the eel resources to withstand the harvest that existing licenced effort is producing. This concern is based on observations by Hurley (1973) that a harvest of 110 metric tonnes (240,000 lbs.) of eels in 1964 contributed to a decrease in the catch of large eels in following years. Thus, over the past three years, the Ministry has adopted a policy of no new licences until the impact of the present harvest can be assessed. This policy has been supported by the Game and Fish Hearing Board, an independent body to which fishermen can appeal a Ministry refusal to issue them a licence.

In conjunction with the no new licence policy, the Ministry increased its monitoring effort on eels. During the 1960's, the Glenora Fisheries Research Station monitored the eel fishery to determine the possible impact of the St. Lawrence Seaway on it. Thus, there was a good data series covering the 1958-1971 time period (Hurley 1972, 1973). The Assessment Unit has taken this data series and extended it to cover the most recent 10-year period in an attempt to assess the effects of both the increased harvest and the eel ladder on the fishery.

ABUNDANCE INDICATORS

As an indicator of abundance, the catch per unit effort (CUE) statistic was examined for the commercial fishery over a 20-year period, 1959-1979. This statistic was calculated for each type of gear, from daily records submitted monthly by the fishermen, and summarized by the three statistical districts mentioned earlier. Figure 2 shows the setline CUE for statistical districts 3 and 6 combined and statistical district 4. Except for a peak in 1972, the CUE in SD 3 and SD 6 fluctuated around 16 kg per 100 hooks until 1979, when it showed a major decline to the second lowest level observed over the 20-year period. Setline effort in SD 4 was not as great as in the other areas, but it also showed little variation except for a decline from 1964 to 1966 and, in recent years, following a 1976 peak. Since running the setlines more than once a day may substantially change the efficiency of capture, we do not feel that setline CUE is a good abundance indicator, unless changes are very significant. Although impounding gear took a lower percentage of the total harvest, we feel that the CUE for this type of gear is more representative of actual eel abundance because it is stationary and does not rely on baiting. Figure 3 shows that the CUE for hoopnets in SD 4 has remained relatively constant, as has the harvest. In SD 3 and 6, however, where the major increase in harvest has occurred, the CUE for trapnets has declined during the same time period.

The recent drop in impounding gear CUE and in the setline CUE indicates that the eel fishery is experiencing very substantial fishing pressure and that it is affecting the abundance of eels in the lake.

BIOLOGICAL CHARACTERISTICS OF THE CATCH

Biological information on the Canadian Lake Ontario eel population and the commercial catch up to 1971 has been published by Hurley (1972, 1973). In his 1973 paper, Hurley concluded that increased fishing pressure had probably contributed to a decrease in the catch of large eels during the late 1960's. In addition, it was speculated that intensive fishing in isolated areas could reduce the population of large eels in those areas because of an apparent tendency toward restrictive home territories. In this section we will be describing recent biological characteristics of the catch and

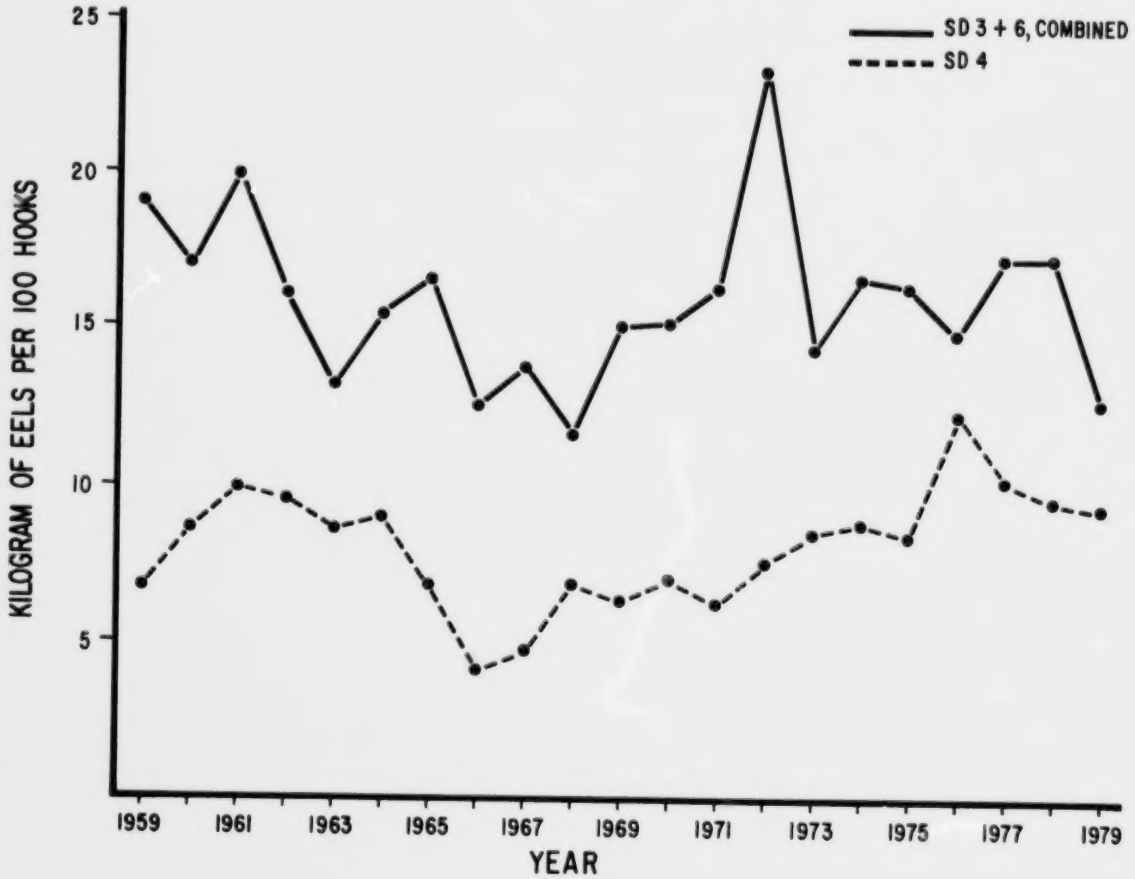

Figure 2. Setline C.U.E. in statistical districts 3 and 6, combined, and statistical district 4.

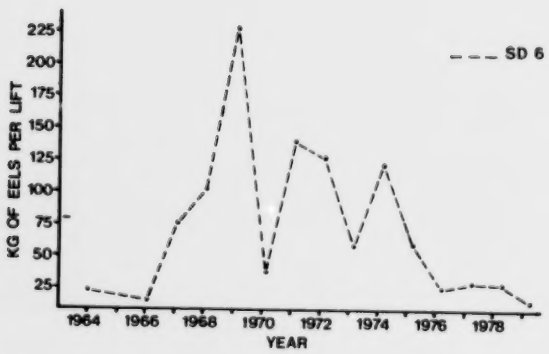

Figure 3(i). Impounding gear C.U.E. in statistical district 6 (trapnet).

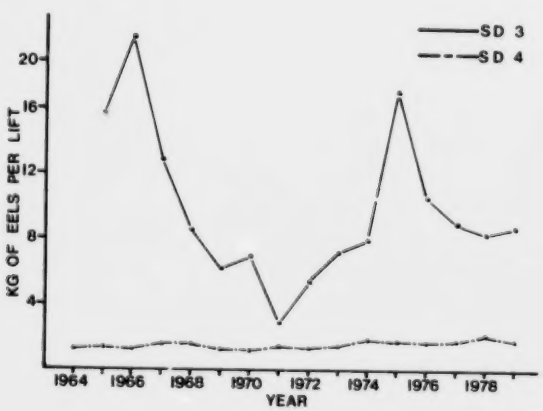

Figure 3(ii). Impounding gear C.U.E. in statistical districts 3 (trapnet) and 4 (hoopnet).

Table 3. Number of eels sampled by gear for the years 1964 to 1979 inclusive.

Year	Setline	Hoopnet	Trapnet	Seine	Total
1964	477				477
1965	513				513
1966	812				812
1967	544				544
1968	99	42	18		159
1969	58	21	332		411
1970	155	69	93		317
1971	391	133	576		1100
1972		NO DATA			
1973	16	4	9		29
1974	61	54			115
1975	89		154		243
1976		NO DATA			
1977	785	301	115	28	1229
1978	1540		93		1633
1979	4972	130	280		5382
Total	10512	754	1670	28	12964

attempting to relate them to changes in harvest level and the influence of the eel ladder.

Commercial catches are sampled from May to September, either at dockside or in the local fish houses. Length measurements are obtained using an eel board composed of a set of three-sided plexiglas troughs with steel rules mounted in the base. The trough allows an accurate measurement of lively eels and is easy to clean. Eels are then placed in a sock and weighed using a spring scale. Rubber gloves afford a better grip on sampled specimens. Two hundred eels are bought each August for otolith aging.

Between 1964 and 1979, sampling effort was concentrated on setlines, since they took 60-65% of the harvest. The majority of samples came from SD 6 setlines, which generally contributed 81% of the total number of eels sampled during this time period (Table 3). Consequently, the data presented here reflect mainly the setline situation, as data from hoopnets and trapnets are scanty.

Figure 4 illustrates the size distribution of eels taken by setlines in SD 6 for the years 1964-1979 (Table 4). The predominant size class in 1964 was 800-899 mm eels. Gradually, the size decreased to the 600-699 mm range and stabilized there in the late 1960's and early 1970's. The 1977 eels showed a recovery to the 800-899 mm range and the histogram for 1977 was very similar in appearance to the histogram for 1964. Nevertheless, in 1978 there was a slight decrease in average size, with eels predominantly in the 700-799 mm class. In 1979, the predominant size class was still 700-799 mm, but there was an increase in the percentage of eels caught in the 500-599 and 600-699 mm classes.

The total number of eels harvested during this time period was calculated using the average weight of eels sampled and total commercial harvest statistics (Figure 4). The number of eels taken by setlines in SD 6 fell from 24,000 in 1964 to 7,000 in 1970, and recovered to 16,000 in 1971. The 1977 and 1978

Table 4. Length frequency distribution (%) of eels caught by setlines in SD 6 (Figure 4).

Year	Sample Size	Length Class (mm)								Average Length (mm)	Total Calculated Catch (no.)
		300-399	400-499	500-599	600-699	700-799	800-899	900-999	1000-1099		
1964	477		0.2	3.6	14.8	27.5	34.6	17.6	1.7	787.3	23,856
1965	513		0.4	8.6	28.6	29.5	24.0	8.1	0.8	729.0	16,942
1966	812	0.1	1.5	13.6	33.2	27.2	17.7	6.2	0.5	699.4	10,715
1971	391		0.2	8.5	38.2	27.2	23.1	2.6	0.2	712.9	16,144
1977	343		0.9	5.1	17.4	30.8	32.6	12.3	0.9	778.8	50,238
1978	801		1.5	7.5	26.4	30.3	24.0	9.3	1.0	750.6	100,684
1979	2788	0.1	0.8	10.8	25.1	29.4	24.7	8.4	0.7	744.1	83,960

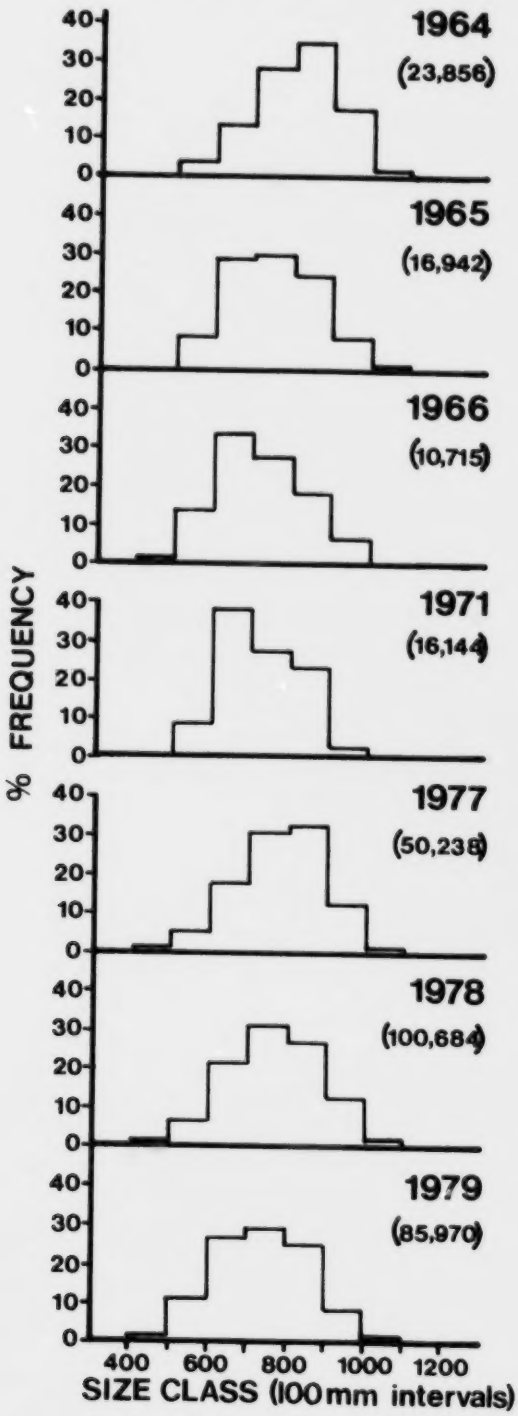

Figure 4. Size distribution of eels taken by setlines in statistical district 6. Total number of eels harvested annually is indicated in brackets.

values of 50,000 and 101,000 illustrate the increased harvest in recent years. In 1979, the total number of eels harvested declined to 86,000 but the size distribution remained similar to that of 1978.

To look at changes in the size of eels taken within a season and again between years, the average total length by month was plotted for several years of data (Figure 5). The eels taken in 1964 and 1978 were very similar in size, with 1978 values being slightly lower. The 1971 values are indicative of the smaller eels taken in the 1965 to 1975 period. The 1979 values show a decrease in size from 1977 and 1978 values. Hurley (1973) observed that there was a decline in the size of eels taken until July and then a slight recovery in August. All the years of data in Figure 5 show this pattern except 1977, when size actually increased in midsummer. The seasonal decline in the size of eels has been attributed to fishing pressure as well as the seaward migration of larger eels, while the recovery in August is considered to reflect summer growth.

Although impounding gear data are scarce, limited sampling within the past three years does support the earlier finding that eels taken in hoopnets and trapnets are larger than those taken by setlines.

Hurley (1973) noted no change in the length-weight regression from 1964 to 1971. The most recent eel data (1977, 1978) indicate there is still no change in this relationship.

Hurley (1972) found the age-length relationship for Lake Ontario eels (1958-1966) to be linear from ages 4 to 14 (Figure 6). The regression of length on age for eels over the linear portion of the curve is expressed by: Length (mm) = 54.94 Age + 112.83. The age-length regression for 1977 eels demonstrated a similar slope but lower intercept (Length (mm) = 56.94 Age + 41.99 for ages 8 to 13). The discrepancy in intercepts between the two regressions arises from the fact that two different individuals aged the two groups of fish. A comparison of aging techniques on otoliths from the same fish demonstrated a 1.2 year difference in aging results. Compensating for this difference would result in the merging together of the two curves. Thus, we feel that no change in the age-length relationship has occurred. In 1977, the average age of eels taken in the fishery was 13.4 years with a range in age of 7 to 19 years.

EEL LADDER CONTRIBUTION TO THE FISHERY

Since 1975 the eel ladder has passed 4.4 million eels over the Moses-Saunders Hydro-Electric Dam at Cornwall. Although 36,500 eels have been tagged, only 23 of them have been recovered to date. If it is assumed that eels arriving in Lake Ontario via the ladder exhibit the same growth characteristics as those observed

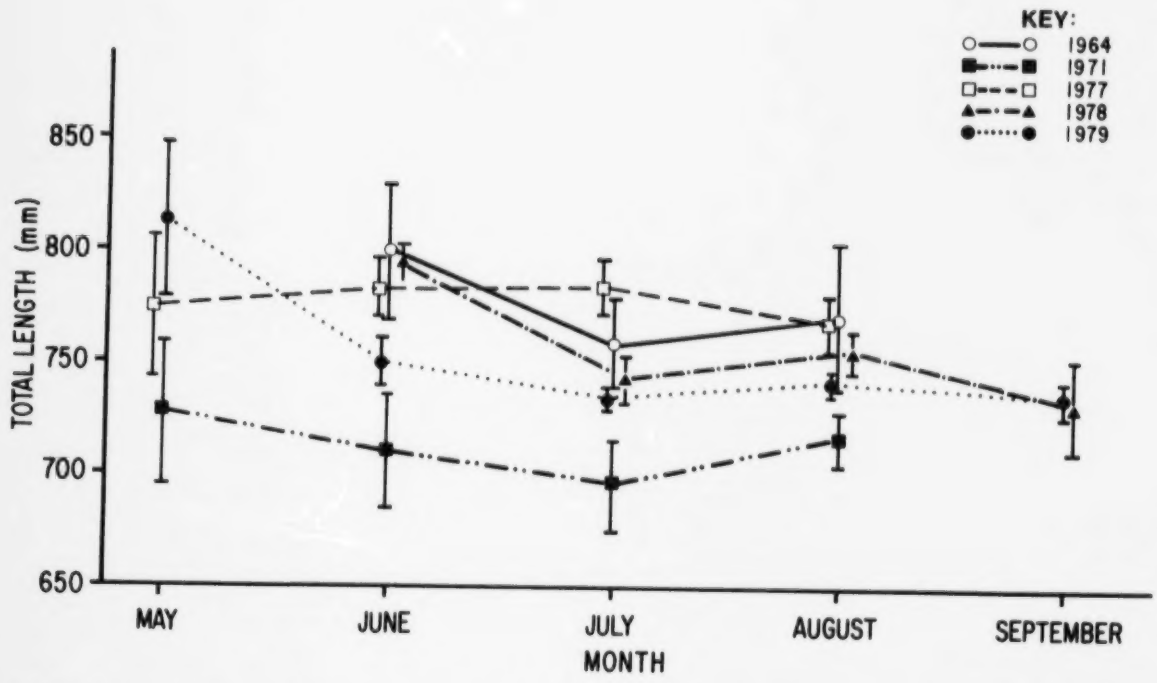

Figure 5. Seasonal variation in size of eels for the years 1964, 1971, 1977, 1978 and 1979. Mean lengths with 95% confidence intervals represent setline eel data from all statistical districts combined.

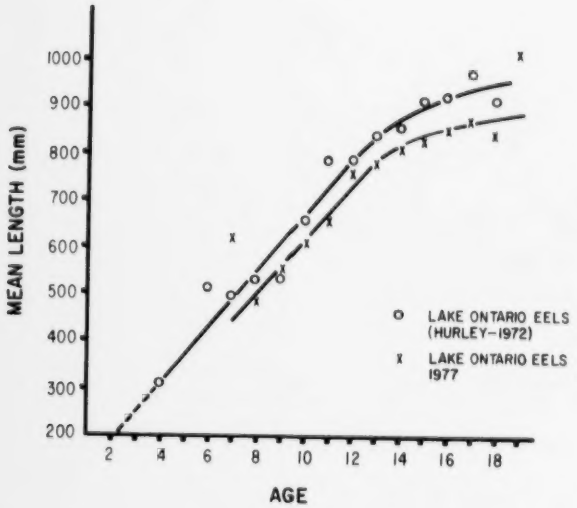

Figure 6. Mean length of eels from Eastern Lake Ontario for each age group.

by Hurley (1972) then the length of time required for them to become vulnerable to the commercial fishery can be extrapolated from Figure 6. Given that the average size of eels moved over the ladder in 1975 was 332 mm (Liew 1976) and that the average size of eel taken in the commercial catch ranged from 740-780 mm in the past three years, then the 1975 migrants would take 7-8 years, or until 1982-83 to become fully vulnerable to the fishery. The substantial increase in catch of 500 and 600 mm eels in 1979 could be preliminary evidence of the eel ladder's contribution to the fishery. This influx of small eels from the ladder could reduce the average size of eels in the catch and cloud the effect of exploitation on the population. The decline in average size observed in 1979 is considered to be a result of both the harvesting of larger eels, by the fishery, and the contribution of smaller eels, by the ladder.

THE ST. LAWRENCE SEAWAY

Interpretation of the data on hand has been confounded by a lack of information on the size distribution in critical years. Nevertheless, it is difficult to reconcile an overexploitation response following a 1964 harvest of 110 metric

tonnes (240,000 pounds) with a recovered size distribution in 1977 at a harvest level of nearly 180 metric tonnes (400,000 pounds). There are three possible explanations for this:

(a) The eel migration was blocked, or severely reduced, during the construction of the seaway.

(b) The larger eels, passed over the eel ladder in the first years, contributed substantially to the 1977 harvest.

(c) A combination of the above.

Hurley (1973) demonstrated that the Moses-Saunders Dam did not constitute a complete blockage to the eel migration into Lake Ontario since he did not observe increasingly older eels and an absence of young eels in the commercial catch. More recent information, however, suggests that a partial blockage may have occurred. As evidence supporting hypothesis (a), we present the following:

1. Seaway construction lasted from 1954 through 1958, during which time coffer dams were built at Iroquois and Cornwall to allow for the construction of permanent structures; waterflow was diverted through narrower sections of the river, increasing the velocity substantially; blasting and dredging occurred over major areas of the river; the shipping canal consisted of 13 locks from Cornwall to Wolfe Island, having a width of 13.7 m. The seaway was opened in 1958 with only 3 locks in place of the previous 13, each one being double the width of the previous locks.

2. Hurley (1973) observed a substantial drop in the number of eels in the 900 and 1000 mm length classes from 1964 until 1971. Eels in the 900+ mm length class would be approximately 15+ years old. If, as he suggests, eels coming up the St. Lawrence are 3 to 4 years old, then these large eels observed in 1964 would have come through the St. Lawrence in 1952 or 1953 just prior to the start of construction. The decline in large eels from 1964 to 1971 could have resulted from a migration blockage or reduction from 1954 to 1958.

3. If the migration resumed in 1958, then the first group of eels through the seaway would be age 10-11 in 1965 (600-700 mm size classes) and would not reach the 900 mm size range until 1970-71. This corresponds well with the preponderence of 600-700 mm eels observed by Hurley from 1965 to 1971. He also noted that large eels were being taken again in 1970 and 1971, although their representation was small. This corresponds with an increase in harvest and some increase in CUE for most gear types.

4. The recent contribution of small eels to the Lake Ontario fishery and a recent increase in CUE for the upper St. Lawrence River has been attributed to the influx of small eels from the eel ladder, demonstrating the blockage created by the Moses-Saunders Dam.

Hypothesis (b), that the larger eels passed over the eel ladder contributed substantially to the recovered size distribution observed in 1977, can best be assessed by looking at the size distribution of the eels passed through the eel ladder from 1974 to 1977. The length frequency data for these eels was extrapolated to 1977 based on observed growth rates of eels in Lake Ontario (Figure 7). This could not account for the high proportion of eels in the 800 mm size class but it could account for the large number of animals in the lower size classes.

Thus, the third hypothesis, which incorporates both ideas, would seem to be the best explanation for the observations on the size and numbers of eels in recent years.

CONCLUSIONS

In summary, the increased fishing pressure over the past 5 years has resulted in a significant increase in harvest that appears to have been sustained, in recent years, by small eels being recruited from the eel ladder. Despite the influx of additional eels, the catch per unit effort for various gear types has been declining. The decline in the average size of eels in the catch over the past three years can be attributed to both the harvesting of larger eels by the fishery and the contribution of smaller ones by the ladder.

Recent management decisions, relating to various species taken by the Lake Ontario commercial fishery, have resulted in a move to manage eels by establishing, in 1980, a 272 metric tonne (650,000 lb.) harvest quota for the lake. As the average size of eel ladder recruits increases, we should see an increase in the average size of fish in the catch, unless fishing pressure is so intense that the young eels are harvested before they reach maximum size or maturity. If the new quota permits the eel ladder recruits to achieve maximum biomass, then the quota may be valid. This quota, however, should be approached on the basis of experimental management until the full impact of the eel ladder can be assessed. A conservative approach must be taken to the harvest of Lake Ontario eels for four basic reasons:

1. The CUE is declining.

2. The American eel is a long-lived animal that does not reach maturity until age 15 to 20. Therefore, any year class is vulnerable to fishing mortality over a number of years and the effects of present harvest levels may not be detected for at least a decade.

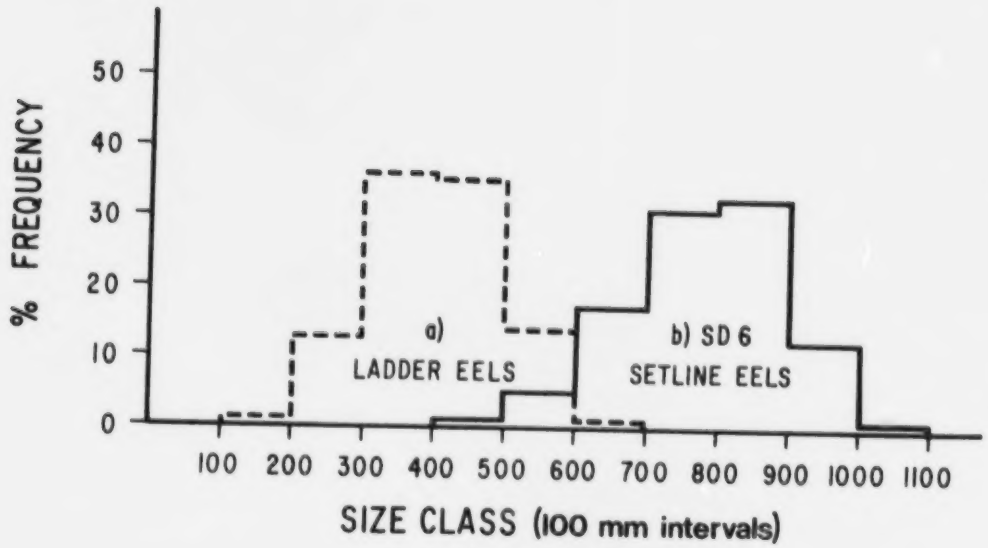

Figure 7. Comparison of:
(a) Expected 1977 length frequency distribution of eels passed over the eel ladder from 1974 to 1976 (extrapolation based on Lake Ontario growth rates (Hurley 1972)), with
(b) Length frequency distribution of SD 6 setline eels sampled in 1977.

3. Lake Ontario eels are predominantly female and thus may represent a major segment of the breeding population.

4. Eels leaving Lake Ontario must contend with two major obstacles:
   a. the turbines at the Moses-Saunders and Beauharnois Dams and,
   b. the St. Lawrence and Maritime fisheries.

ACKNOWLEDGEMENTS

We thank the various field crews for the collection of biological data and the eastern Lake Ontario commercial fishermen and buyers whose cooperation made this study possible. C. H. Wood deserves special recognition for drafting the figures. The Napanee District Office is acknowledged for the support it provided during the investigation.

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IMPACT OF THE EEL LADDER ON THE UPSTREAM MIGRATING EEL (*Anguilla rostrata*) POPULATION IN THE ST. LAWRENCE RIVER AT CORNWALL: 1974-1978

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K6H 5V7[1]

ABSTRACT

An eel ladder was constructed in 1974 at the Moses-Saunders Dam, situated in the St. Lawrence River at Cornwall, Ontario, to facilitate the upstream migration of the American eel (*Anguilla rostrata*). Several million eels passed through this fishway between 1974 and 1979. Age, length and growth characteristics of the eels using the ladder were examined annually between 1974 and 1978. Trends in the reduction of mean weight and mean length at corresponding ages suggest that the eel ladder has reduced the effect of the dam as an obstacle to eel migration. The results suggest that during the first year of operation the majority of the eels moved were those whose migration had been blocked by the dam for several years. In subsequent years, the ladder appears to have moved eels into the upper St. Lawrence River almost as fast as they reached the dam.

INTRODUCTION

The completion of the Moses-Saunders Hydro-Electric Power Dam at Cornwall, Ontario, in 1959 created a major obstacle to the up-river migration of young American eels (*Anguilla rostrata*) from the St. Lawrence River to Lake Ontario. The dam is 25 m high and 1 km wide. After 1959, thousands of eels were seen congregating at the foot of the dam each summer.

The presence of such large numbers of eels below the dam indicated that the natural migration run up the St. Lawrence into Lake Ontario was being affected to some extent. Also, the presence of large numbers of small eels in the tailwaters of the dam caused serious problems with respect to repairs to the dam's turbine housings. The eels clogged the pump intakes and made dewatering difficult, if not impossible.

To alleviate these problems, a prototype eel ladder was designed in 1974 by R. E. Whitfield. It has been operating since 1974. Modifications and adjustments have been made to facilitate eel movement in the ladder. This paper describes the impact of the eel ladder on the sizes of the migrating eels in the St. Lawrence River from 1974 to 1978.

MATERIALS AND METHODS

The fishway is installed in one of the three ice chutes of the dam on the Ontario side of the river. The design and operation of the eel ladder are described by Eckersley (1980).

The eel ladder operated from mid-June to mid-September or mid-October. Annual variations in operating dates were dependent on the timing and length of the eel run, which in turn appear to be strongly linked to seasonal trends in water temperature. Periodically during the run, the length and growth characteristics of a random sample of eels using the ladder were examined.

The total length, from the tip of the lower jaw to the posterior end of the middle caudal rays, was measured in millimetres. Weight was determined to the nearest gram. Otoliths were collected and analysed to establish age and growth characteristics following a method described by Liew (1974). Surface water temperatures were taken periodically at the top of the ladder every year, except 1974.

RESULTS AND DISCUSSION

More than 3.5 million eels moved through the ladder to the upper St. Lawrence River between 1974 and 1978. The largest eel was 840 mm in length and 1140.0 grams in weight, while the smallest was 130 mm in length and 1 gram in weight. About eighty-five percent (85%) of the eels were between 200 and 450 mm in length.

At the beginning of the season, the migrating eel population was predominated by larger fish. Young eels were most abundant during the peak of the season, decreasing in number as the season progressed and water temperatures declined. Larger fish were more abundant again at the end of the season.

The biweekly length composition of eels passing through the ladder shows a general decline in total length from 1975 to 1978 (Figure 1). Although the lengths of these fish, especially those of 1976, overlapped at certain periods, it probably was an intensification of the effect of water temperature on the sizes of migrant eels, rather than the fluctuation of fish sizes during those periods.

Before the ladder was installed, the eels were forced to remain downstream where they grew in size. As a result, during the first two years

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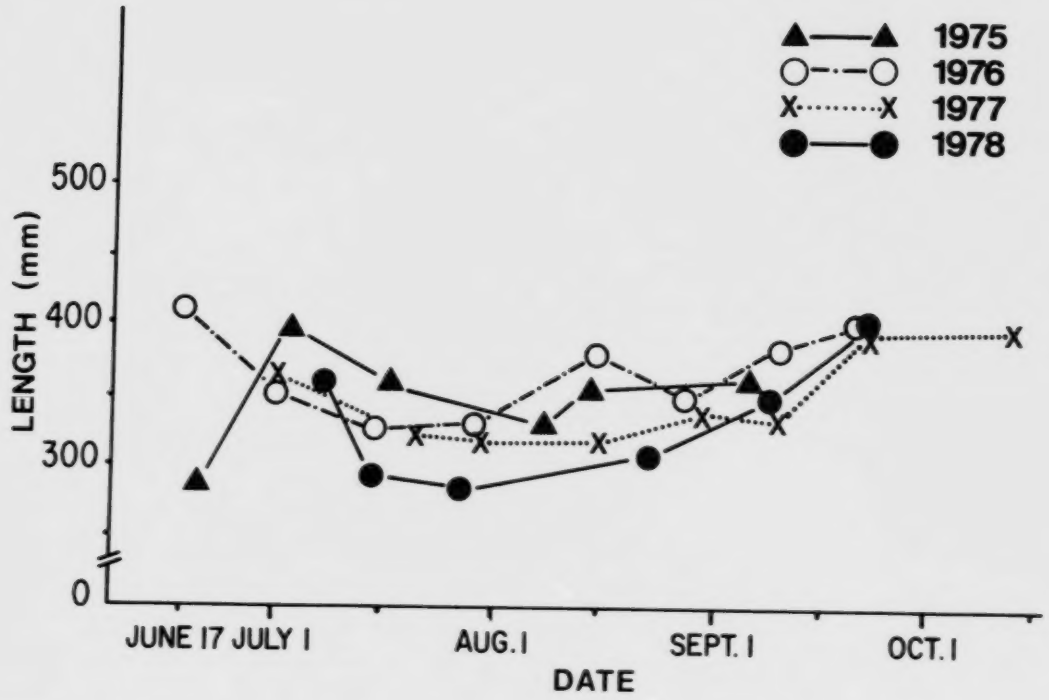

Figure 1. Bi-weekly length composition of eels passing through the eel ladder during the summers of 1975 to 1978.

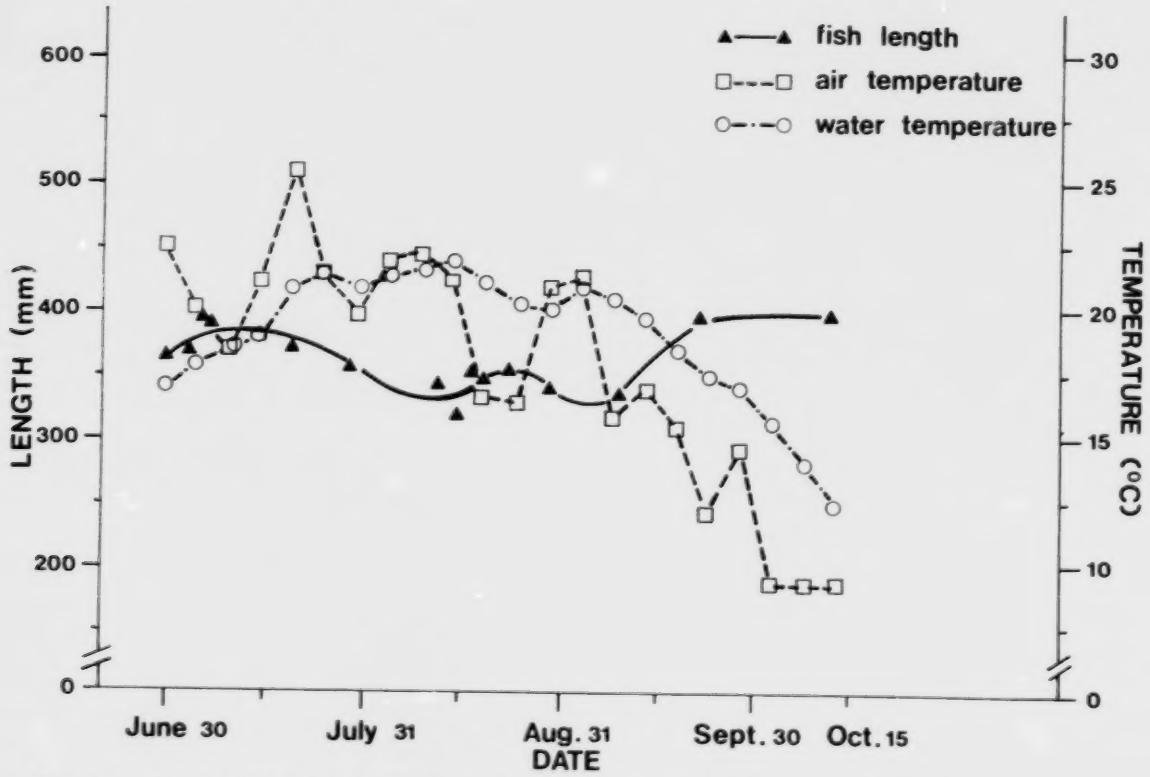

Figure 2. Weekly length distribution of eels collected from the eel ladder in the summer of 1977.

of operation, many of the eels ascending the ladder were large. By the third and fourth year, however, the majority of the eels were small, indicating that these eels were passing upriver to Lake Ontario without prolonged delay.

The size of migrating eels was inversely proportional to water temperature, as demonstrated by Figs. 2 and 3. The average size of 1977 eels decreased as the water temperature increased during the season (Figure 2). A drastic drop in temperature at the end of August was followed by a sharp increase in the size of the migrants. At the end of the season, the temperature was low and larger fish were ascending the ladder. As Figure 3 indicates, there also was an inverse correlation between water temperature and size of migrating eels during 1978.

Unexpectedly, regression analysis failed to detect a significant correlation between mean size and water temperature (r^2 = .36, P = .05). This is probably due to a small sample size and, as observations suggest, the fact that there was a 2-3 day lag between the temperature changes and the corresponding change in the length distribution of the eels. The sampling intervals, when lengths were measured, were short and the response of the length distributions may not have been covered.

As eels ascended the dam via the ladder to the upper St. Lawrence River, they were replaced by fish coming from the lower river. As the older fish moved away, they were replaced by a newly arrived younger population.

The eels collected in September of 1975 had much greater mean lengths at corresponding ages than fish collected in September of 1974 (Figure 4). As the slower-growing fish, which had been forced to stay below the dam for a prolonged period, moved over the dam during the 27-day operation in 1974 and the first part of 1975, they were replaced by much faster-growing young eels coming from the lower river.

The relationship between water temperature and the size of migrating eels has been discussed. Unfortunately, no systematic records of water temperature and the sizes of eels passing through the ladder were maintained in the early years of operation. Nevertheless, the air temperatures during the summers of 1974 and 1975 were similar and there were no drastic water temperature changes. Therefore, it is assumed that water temperatures did not cause the differences in the lengths at corresponding ages between samples. It is believed that the differences actually reflect the change in the eel population structure below the ladder after the installation of the eel ladder (Figure 4).

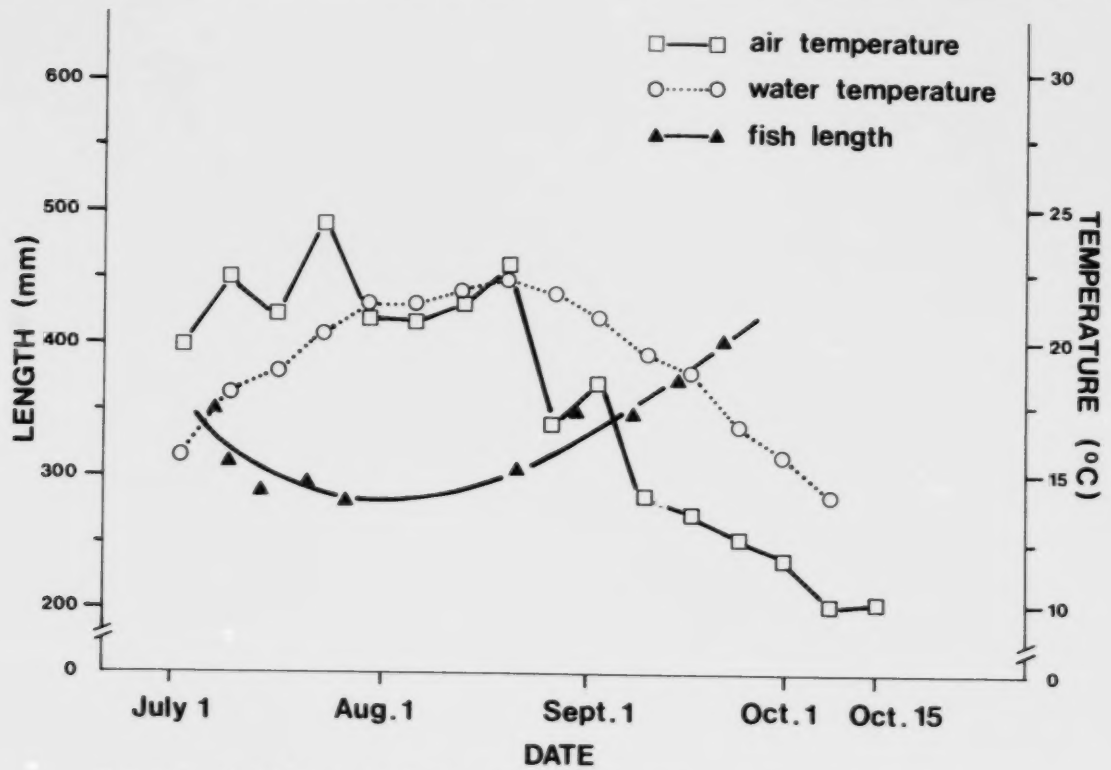

Figure 3. Weekly length distribution of eels collected from the eel ladder in the summer of 1978.

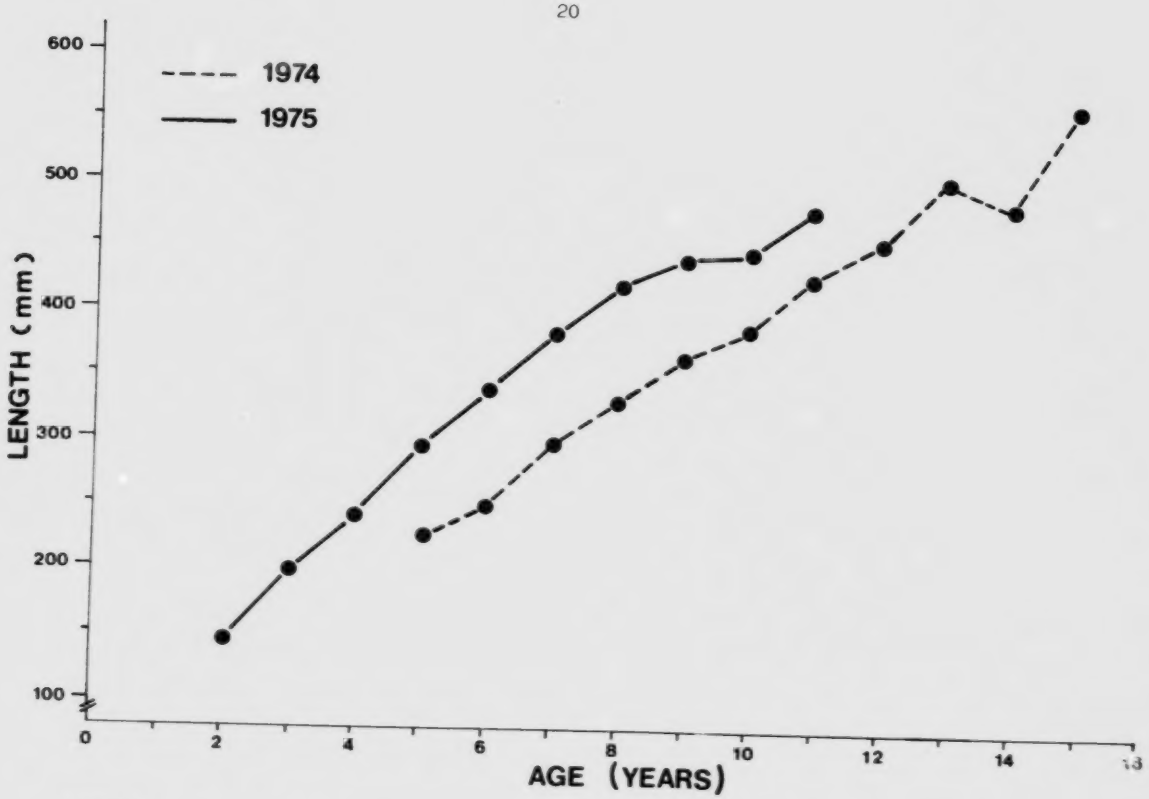

Figure 4. Comparison of mean length at age of eels collected in September of 1974 and 1975.

The peak of the migration run usually corresponded with the warmest period of the season. Presumably, it was a period when the optimum migrating conditions prevailed and the average size of the migrants was the smallest of the season. When the age-length compositions of eels collected at the peak of their migrations from 1975 to 1978 were compared (Figure 5), there was only a slight difference in fish length for the corresponding age groups. In general, the 1975 fish were the slower growing ones, while the 1978 fish belonged to faster growing groups. The 1976 and 1977 fish fell between these two groups. Due to the difference in time of year of collection, the 1974 fish have been included for reference only. The present data indicate that as older fish moved through the ladder they were replaced by faster-growing younger fish from the lower river. These fish probably represent the normal migrating eel population in the St. Lawrence River. These fish did not prolong their stay below the dam before moving upriver to Lake Ontario.

SUMMARY

The data indicate that the eel ladder has had a significant influence on the movement of eels into the upper St. Lawrence River. The greatest effect was evident during the first two years of operation. The slower growth rate and larger size of the eels initially moved over the dam in 1974 suggest that those eels had previously been prevented from moving upriver by the dam. Between 1975 and 1978 the mean sizes continued to decline, but at a much slower rate, and the growth rates have remained relatively constant. The relative consistency of these two characteristics, compared to the 1974 sample, suggests that eel migration was not blocked by the dam between 1975 and 1978 to the same extent as it was prior to the installation of the ladder. If this is the case, the eels moved over the dam are a segment of the Lake Ontario-upper St. Lawrence River stock which, prior to 1974, were not continuing their migration past Cornwall.

All eels were not prevented from moving past Cornwall between 1958 and 1978. An unknown proportion of the migrating eels must have used the Seaway locks to bypass the dam. This is supported by the failure of the Lake Ontario fishery to collapse between 1958 and 1974 (Kolenosky and Hendry 1982). Nevertheless, Kolenosky and Hendry (1982) have found a recent increase in both the recruitment of young eels into the Lake Ontario fishery and the CUE of eel fishermen in the upper St. Lawrence River. Their hypothesis, that this is due to some extent to the influx of eels resulting from the operation of the eel ladder, is supported by the changes in length, age and growth exhibited by the eels migrating through the ladder between 1974 and 1978.

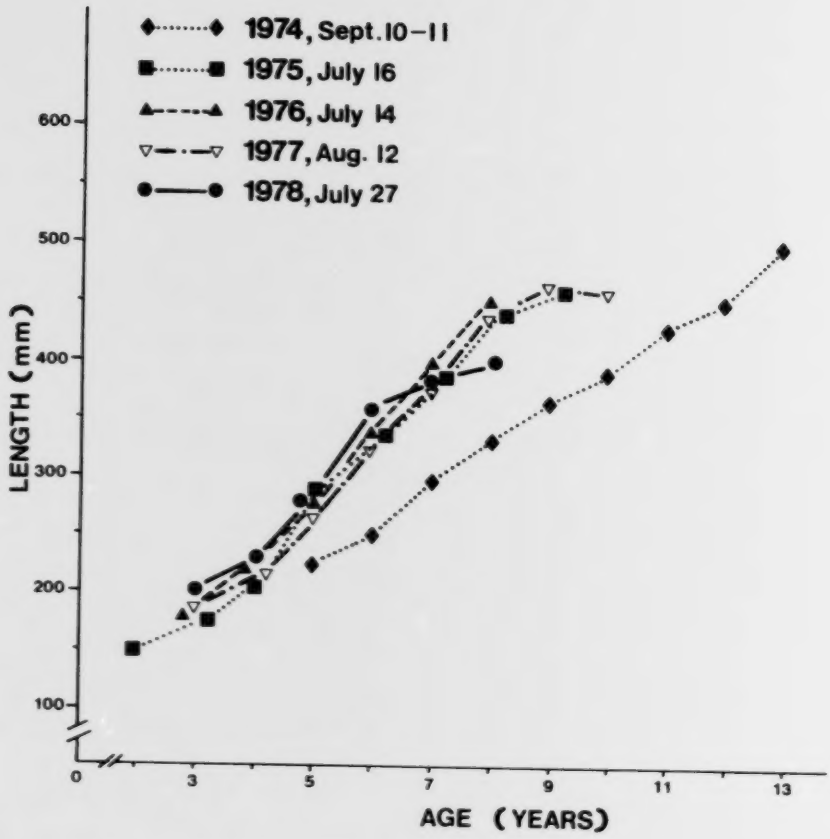

Figure 5. The age-length relationships of eels passing through the ladder during the peak of their migration from 1975 to 1978. The 1974 data were included for comparison.

ACKNOWLEDGEMENTS

I would like to thank the staff of the Ontario Ministry of Natural Resources, Cornwall District, for their support in operating the eel ladder. Special thanks is due to M. J. Eckersley for his critical review of the manuscript. The Fisheries Industrial Development Branch, Department of Fisheries, Ottawa, and Ontario Hydro are acknowledged for their financial support.

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ONTARIO-DISCUSSION

1. Young eels arriving at the Cornwall eel ladder have been aged as 4 and 6 years. The discrepancy is due to difficulty in aging.

2. The question was raised regarding the variability in maturation times within Lake Ontario eel populations referred to (5 to 20 years), i.e. seaward migrating silver eels.

   It was suggested that this could be related to favourable environmental influences, which might lead to rapid maturation and emigration. Asked if there is a way of measuring the number of eels leaving Lake Ontario, the speaker indicated that the number of eels leaving the lake is an unknown.

3. A question was raised on the necessary size of escapement from Lake Ontario. D. Kolenosky indicated she did not know the necessary escapement size but stated that some of the eels from Lake Ontario must be required for reproduction. She added that there are a number of obstacles to Lake Ontario eels heading for the Sargasso Sea, in addition to the commercial fishery on the Lake, e.g. hydro electric turbine mortality at two sites, harvesting by the lower St. Lawrence River fisheries and other unknown factors.

4. The question was raised concerning the preferred location in a river of downstream migrant eels. It was indicated that European evidence suggests that migrant eels travel deep in the centre of rivers.

   Related to this subject, Ontario Hydro is involved in eel guiding studies using various types of lights. Another study involves the use of pumps to move eels from turbine intake areas.

5. Commercial fishermen referring to their experience suggested that eel growth rates were dependent on available food supply (forage species - alewife, shad, smelt, cyprinids).

QUEBEC

EXPLOITATION OF THE AMERICAN EEL *Anguilla rostrata* (LeSueur) in Quebec

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Eel fishing *(Anguilla rostrata)* in fleuve Saint-Laurent has had a very long history. Native indians in the Quebec region fished for eels long before the arrival of the first French explorers. Later, eel fishing became a means of livelihood for Quebec settlers, and then an important trade, which according to Eales (1972) constituted 70% of the Canadian commercial eel catch.

Statistics of Fisheries and Oceans, Canada, for 1978 show that 49% of the Canadian eel catch comes from fleuve Saint-Laurent and rivière Richelieu, representing a total of 527.9 metric tonnes and an income of $1,924,254 to the fishermen.

JURISDICTION

The eel fisheries in Quebec are under the jurisdiction of two Ministries: "Loisir, Chasse et Pêche", which is responsible for the inland fishery and "Agriculture, Pêcheries et Alimentation", which deals with the estuary fishery.

Both Ministries issue fishing licences, regulate the fisheries, and enforce the fisheries laws.

DELINEATION OF THE JURISDICTION

Quebec's inland eel fisheries occur in rivière Richelieu and along fleuve Saint-Laurent, up to Nicolet and Champlain counties (Figure 1). The estuary fishery extends from Portneuf and Lobtinière counties up to that of Rivière-du-Loup.

REGULATIONS

The commercial exploitation of eels is regulated by Federal fisheries laws as well as the Quebec fishing regulations. The main regulations pertaining to the eel fishery are a minimum mesh size (stretched) of 5.7 cm and a minimum distance of 228.6 m between the fisheries (fishing stations).

The harvesting of eels less than 45.7 cm (18 inches) in length is prohibited. The maximum number of fishing licences issued for lac Saint-Pierre is 42 with each fisherman limited to 40 trap nets. *(See Secretary's note).

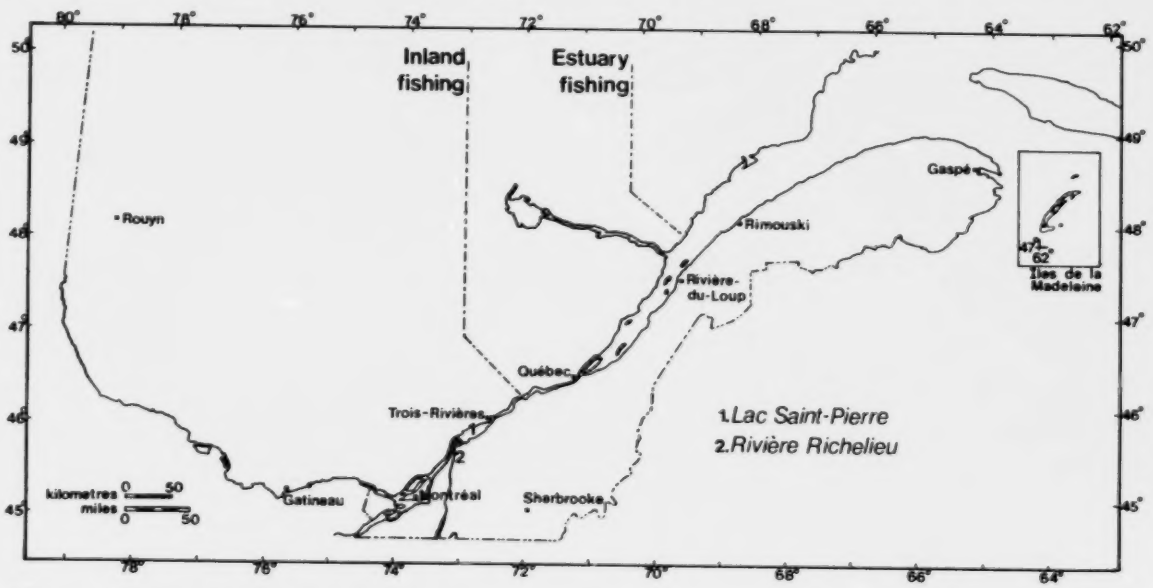

Figure 1. Location of the eel fisheries of Quebec.

FISHING METHODS

Trap nets are used in the inland fisheries along fleuve Saint-Laurent, whereas there is a fixed fishery in rivière Richelieu. The estuary fishery is fixed and transitional in the tidal zones.

TYPES OF EELS

Inland catches consist almost exclusively of yellow eels, whereas estuary catches consist mainly of silver ones.

QUANTITY AND VALUE OF LANDINGS

The overall landings of eels in Quebec declined sharply in 1970 due to a ban on fishing. As a consequence, the eel landings did not increase substantially until 1973. For the last five years, the total annual catch has fluctuated around 455 tonnes (Figure 2, Table 1) with an average annual catch of 130 tonnes for the inland fishery and 348 tonnes for the estuary fishery.

The 1978 catch for the province of Quebec was 527.9 tonnes with a total value to the fishermen of approximately $1,925,000. This represents 49% of the total Canadian eel catch, 75% of which comes from the estuary fishery and 25% from inland catches (Figures 3 and 4).

In 1978, eels ranked fourth in value to the fishermen among commercially exploited species, exceeded only by cod, lobster and shrimp (Table 2). They represented 7% of the total catch, all species combined.

NUMBER OF FISHERMEN AND CATCH

In 1978, 102 fishermen were engaged in the inland fishery. The average catch was 1.3 tonnes. The average catch in lac Saint-Pierre (42 fishermen) was 2.2 tonnes with a total catch of 89.9 tonnes. This represents 68% of the Quebec inland catch and 8% of the overall Canadian catch.

The one eel fishery of rivière Richelieu is by far the most productive with a total catch of 36.3 tonnes, representing 28% of the Quebec inland fishery and 4% of the entire Canadian catch.

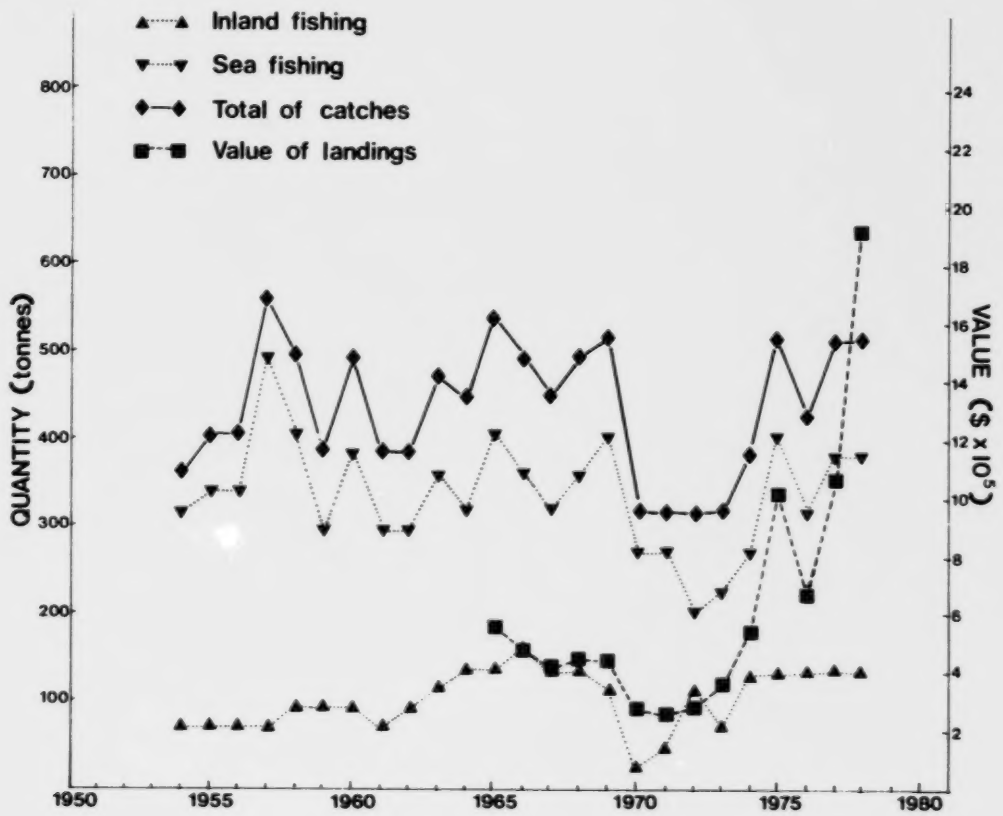

Figure 2. Quantity and value of eels landed caught by all Quebec fisheries (1954-1978).

Table 1. Quantity and value of eel landings for Quebec fisheries.

Year	Inland fishery		Estuary fishery		Total Quebec fisheries	
	tonnes	$	tonnes	$	tonnes	$
1954	65.8	—	307.3	—	373.1	—
1955	74.5	—	339.4	—	413.9	—
1956	70.7	—	337.6	—	408.4	—
1957	70.9	—	504.8	—	575.8	—
1958	95.1	—	403.7	—	498.9	—
1959	93.2	—	301.4	—	394.6	—
1960	101.2	—	392.2	—	493.4	—
1961	78.9	—	306.1	—	384.9	—
1962	99.9	—	286.5	—	386.4	—
1963	119.9	—	353.1	—	473.0	—
1964	138.5	—	312.3	—	450.8	—
1965	145.9	112,550	407.9	449,662	553.8	562,212
1966	155.9	120,345	352.4	372,890	508.3	493,235
1967	131.0	95,336	317.8	322,258	448.8	417,594
1968	140.0	95,676	365.9	355,002	505.9	450,678
1969	122.8	78,506	398.8	369,309	521.6	447,818
1970	30.4	19,465	283.2	262,256	313.7	281,720
1971	43.4	33,524	270.8	238,812	314.3	272,346
1972	105.8	81,612	209.8	208,113	315.5	289,724
1973	78.5	67,477	232.1	296,762	310.6	364,239
1974	125.0	137,816	265.7	410,041	390.7	547,856
1975	129.1	142,354	400.4	882,760	529.5	1,025,114
1976	131.6	168,261	294.3	506,088	425.9	674,349
1977	133.1	243,476	381.5	832,688	514.6	1,076,164
1978	131.6	246,547	396.3	1,677,708	527.9	1,924,254

Source: Dussault (1979). — Data not available.

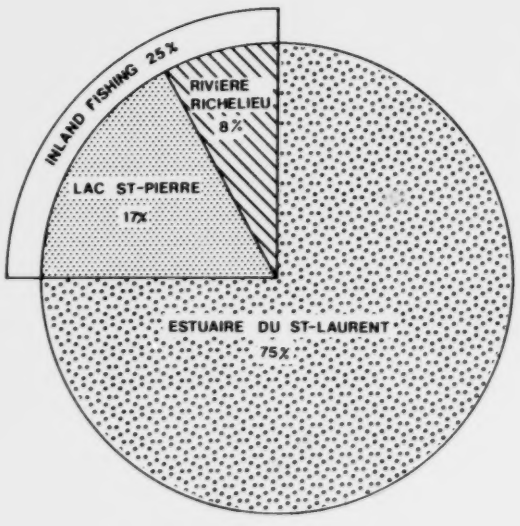

Figure 3. Distribution of landings for Quebec fisheries.

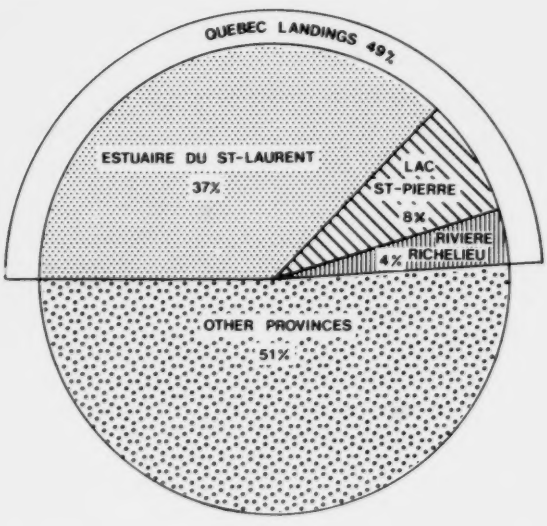

Figure 4. Distribution of Quebec landings in comparison to Canadian catches.

Catch data for each estuary fishery are not available for 1978. The average catch for each fishermen was approximately 2 tonnes.

Table 2. Quantity and value of fish landings, Quebec, 1978.

Species	Quantity tonnes	%	Value $	%
Cod	26,325.10	43.0	9,788,234	33.9
Redfish	8,289.45	13.6	1,727,546	6.0
Atlantic Halibut	62.07	0.1	174,829	0.6
Flatfish	4,894.88	8.0	1,292,134	4.5
Hake	447.82	0.7	87,113	0.3
Greenland Halibut	4,466.26	7.3	1,387,456	4.8
Herring	5,885.37	9.6	1,003,099	3.5
Mackerel	941.74	1.5	160,044	0.5
Salmon	79.84	0.1	285,532	1.0
Smelt	594.14	1.0	221,741	0.7
Scallop	90.53	0.1	363,586	1.3
Lobster	1,597.09	2.6	5,386,355	18.6
Crab	2,409.60	3.9	1,445,516	5.0
Shrimp	3,842.99	6.3	3,668,333	12.7
Other Species[a]	1,352.20	2.2	1,904,806	6.6

[a] includes eel landings from estuary fishery, but not from inland fishery.

Source: Bureau de la statistique du Québec (1978).

EXPORT MARKET

Traditionally, Canada exports about 75% of its total eel catch (Eales, 1972). It was not possible, however, to determine the percentage of Canadian eels exported in 1978, as they were combined with "other species" such as mackerel and perch. Nevertheless, according to Quebec exporters, almost all Quebec catches are exported to Europe as follows: Germany, 58%; the Netherlands, 16%; Sweden, 16%; Denmark, 4%; France, 4% and Belgium, 2%.

AVERAGE PRICE PAID TO FISHERMEN

In 1978, fishermen received $1.87 per kilogram for yellow eels and $4.23 per kilogram for silver eels. In 1979, the prices were $3.35 and $4.14 per kilogram, respectively, an increase of 83% for yellow eels and 90% for silver eels, compared to 1977 (Table 3).

Table 3. Average price paid to fishermen from 1965 to 1978, in dollars per kilogram.

Year	Yellow eel ($/kg)	Silver eel ($/kg)
1965	0.77	1.10
1966	0.77	1.06
1967	—	—
1968	—	—
1969	0.64	0.92
1970	—	—
1971	0.77	0.88
1972	—	0.99
1973	0.86	1.28
1974	1.10	1.54
1975	1.10	2.20
1976	1.28	1.72
1977	1.83	2.18
1978	1.87	4.23
1979	3.35	4.14

Source: Labrecque (1979).
— Data not available.

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QUEBEC - DISCUSSION

1. In answer to a question concerning the increase in the price for yellow eels in 1979, it was suggested that it was probably due to supply and demand, i.e. competition among buyers.

2. A question was raised concerning the legal size limit of eels harvested commercially. It was indicated that 18 inches had been the official legal limit but 8 inches, which appeared in error in the regulations, has been enforced.

SECRETARY'S NOTE:

A search of current provincial Fishery regulations, supplied by the Federal Department of Fisheries and Oceans, shows that all the Atlantic provinces (Quebec, New Brunswick, Prince Edward Island, Nova Scotia and Newfoundland) state 8 inches as the legal size limit for eels. The Ontario Fishery regulations make no reference to a legal size for eels. The matter was discussed with Fisheries and Oceans, Ottawa, but they were not aware that the legal size limit had ever been 18 inches.

MARITIMES

A REVIEW OF THE STATUS AND MANAGEMENT OF COMMERCIAL FISHERIES FOR AMERICAN EELS (*Anguilla rostrata*) IN THE MARITIME PROVINCES

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The fishery for American eels (*Anguilla rostrata*) contributes significantly to the value of inland fisheries in the Maritimes. Its value is exceeded only by the fisheries for gaspereau, Atlantic salmon and American smelt, respectively. Between 1968 and 1978, an average of 465 metric tonnes of eels worth $261,000 was harvested annually. Total Maritime catches have slowly declined, but increased purchase prices have resulted in the catch value remaining relatively constant (Table 1).

The major eel fishing regions of the Maritimes include the Gulf of St. Lawrence and Northumberland Strait coasts and the St. John River in New Brunswick, the eastern and western sections of Prince Edward Island, and the Margaree River, LaHave and Medway River areas and the Pubnico-Yarmouth area of Nova Scotia (Figure 1). Inter-provincial differences in eel production apparently relate not only to the number and size of accessible rivers, lakes and estuaries but perhaps more importantly to the geomorphology and water quality of the system. New Brunswick has numerous moderately-sized rivers of moderate gradient and good water quality along its northeastern coast, many of which possess extensive estuaries. Although the estuary of the Miramichi River is a major eel producer, few eels are caught in its upper reaches or in the nearby Restigouche River, for reasons that are unknown. The extensive, often shallow, lake area associated with the Saint John River is a significant factor in its high production of eels. Only a small portion of the elvers reaching Mactaquac Dam are passed upstream but it is not known if adverse effects have occurred to the upriver eel stock since completion of the dam in 1968. Prince Edward Island has relatively small, low gradient streams draining into extensive estuaries, while most Nova Scotian streams along the Atlantic coast are small to moderate in size with moderate gradients, and they drain from extensive lake systems. Relative to New Brunswick and Prince Edward Island streams, many Nova Scotian streams have low pH, low total dissolved solids, high colour and low productivity.

The higher productivity of the major lake, river and estuarine systems, coupled with a

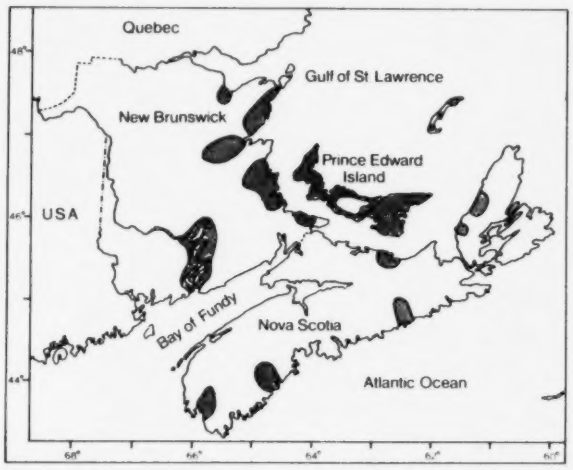

Figure 1. The major eel fishing regions of the Maritimes.

Table 1. Commercial landings (tonnes) and value ($,000) of American eels in the Maritime provinces, 1968-1979.

Year	Nova Scotia		New Brunswick		Prince Edward Is.		Total	
	Weight	Value	Weight	Value	Weight	Value	Weight	Value
1968	49	18	165	35	131	32	344	85
1969	62	23	264	58	195	43	521	124
1970	74	31	368	111	240	98	477	240
1971	102	48	387	202	351	194	840	444
1972	62	34	300	174	272	183	634	391
1973	47	33	247	152	157	105	452	290
1974	43	29	176	117	101	60	320	206
1975	42	36	171	143	103	69	317	248
1976	27	24	197	146	94	72	318	242
1977	15	14	265	216	100	81	380	311
1978	65	65	126	124	113	100	305	289
1979[a]	30	46	148	207	94	121	272	374
Mean	51.5	33.4	234.5	140.4	162.6	96.5	431.7	270.3

[a] preliminary figures

general ease of site access, nearness to good roads and buyer availability, has resulted in a concentration of the fisheries in these areas. Consequently, the eel resources of New Brunswick and Prince Edward Island are exploited more fully and intensively than those of Nova Scotia, where many smaller river systems are ignored.

Catches vary markedly between provinces, with New Brunswick consistently producing the largest catch, followed by Prince Edward Island and Nova Scotia (Table 1). During the 1970's, eel landings in all three Maritime provinces generally have declined, but now show signs of stabilizing. The catch decline has been greatest. both relatively and absolutely, in Prince Edward Island where the mean catch from 1976 to 1979 was 38% lower (62 metric tonnes) than the 1968-1979 mean catch, as compared with 22% (50 tonnes) in New Brunswick and 33% (17 tonnes) in Nova Scotia. In general, the catch declines in all three provinces can be attributed to overfishing, at least on a local basis, with the effects of market and natural variability superimposed on this trend. Nova Scotia's increased harvest in 1978 probably reflects more intensive exploitation of known resources and the development of new fishing areas.

The types of fishing gear employed ranged from eel pots to hoop nets of various form, such as wing and fyke nets, to weirs, depending upon the nature of the fishing site. Weirs are popular in certain Nova Scotian rivers, groups of wing nets with leaders of up to 600 m in length are used in lakes tributary to the Saint John River, fyke nets are used in Margaree Harbour and eel pots are used in estuaries and still-waters. A fundamental understanding of the conduct of American eel fisheries in the Maritimes can still be obtained from the 1968 report on "The Eel Fisheries of Eastern Canada" by J. G. Eales. In 1978, the Nova Scotia Department of Fisheries completed a survey of the distribution, methodology and production of the eel fisheries in the province. There are no similar surveys for New Brunswick or Prince Edward Island.

No coherent policy exists for the management of the American eel resource in the Maritimes. Prior to 1977, fishery management was the primary responsibility of the Resource Branch, albeit with strong input from the Field Services Branch whose responsibility was enforcement of the regulations, licencing of the fishery and collection of statistics. The differing objectives of Resource Branch biologists and Field Service Branch fishery officers, coupled with the low priority accorded the eel fishery, often led to inaction.

Since 1977, the Maritimes has been divided into six management areas within which the area manager has primary responsibility for fishery resource management. The area manager, or a committee under his authority, integrates the advice of biologists, fishery officers, the public and interested fishermen's organizations, etc., to arrive at a workable management policy.

Since the eel fishery is not a priority topic in all management areas, management policies are a new development. In fact, only the Saint John River fishery has a policy under formulation. The policy includes clauses (a) restricting licence issuance to Canadian citizens resident in the counties where eel fishing occurs; (b) restricting fishermen to a single licence which permits use of up to 40 gear units, with three eel pots being equivalent to one trap or fyke net; (c) limiting the distribution of fishing gear to three sites per county or five in total, with each site including both shores of a river or one shore of a lake for a distance of three miles; (d) invalidating a fishing privilege if regular fishing activity does not occur, and (e) establishing a closed season from January 1 to June 30 of each year. Upon finalization, several of the provisions of this policy could be implemented on a province-wide basis.

Regulations governing the conduct of the eel fishery vary widely between provinces but all are minimal, non-comprehensive and seem designed more to guard against the capture of Atlantic salmon and brook trout than to control the eel fishery. For example, both New Brunswick and Prince Edward Island have closed estuaries frequented by salmon and trout to fishing for eels by spears and torches or other artificial lights, except during a short period in the autumn. In non-tidal waters of New Brunswick, such fishing is prohibited all year, but Nova Scotia has no similar regulations. New Brunswick has no seasonal restriction on eel fishing with nets, traps or weirs except on one small river; whereas in Nova Scotia, a seasonal closure applies to brush weirs and trap-nets in inland waters, but not to other gear or to estuaries. Prince Edward Island simply closes all waters to fishing by weirs, traps or pots from December 1 to August 15. All provinces enforce a minimum capture and retention size of 20 centimetres, ostensibly to prevent the exploitation and export of elvers, which could be detrimental to the establishment of eel aquaculture programs, rather than to prevent over-exploitation of the adult stock. A special licence from the Minister is now required to conduct an elver fishery, but every encouragement would be given to fishermen who wished to conduct such a fishery both for the benefit of local aquaculture and, under certain conditions, for export.

The biological status of the American eel resource in each Maritime province is virtually unknown. Little work has been done since the pioneering studies of ten or twenty years ago and current information for management purposes is almost unobtainable. Surveys of a part of the commercial eel fishery of the St. John River in 1974 and 1979 permit a comparison of the size composition and its seasonal change. The Nova Scotia Department of Fisheries recently completed

a life history survey of eel stocks in several rivers but I know of no similar information for Prince Edward Island.

The only available index of the status of eel stocks is the trend in annual reported sales, by Fishery District, the accuracy and completeness of which are often inadequate. In any case, the statistics collection system was not designed with the needs of fishery management in mind. Reported sales data, loosely referred to as catch data, is collected and submitted on a monthly basis by the local fishery officer using copies of buyer's purchase slips. Sales are not recorded by district of capture but by district of sale, which may differ from the district of capture, thereby creating difficulty in analyzing the statistics for catch-effort purposes. Information on the catches of individual fishermen or specific river systems generally is impossible to obtain. At present there is no systematic or centralized collection of fishing effort data, in any form, although licencing information soon will be obtainable from a central computer system. Sales data already are. Individual fishery officers can be induced to provide effort data, in the form of the number of licences issued and gear units authorized, but the number of gear units actually fished and the duration of fishing activity can only be crudely estimated. Such individual efforts are not a satisfactory solution to a serious problem. The use of logbooks by individual fishermen might resolve some of the statistical problems, but could create others.

An examination of the Saint John River eel fishery which, since 1968, has supplied an increasing proportion (from 5 to about 50%) of the total New Brunswick catch, will provide insight into the conduct of a major eel fishery. Virtually all fishing is confined to three

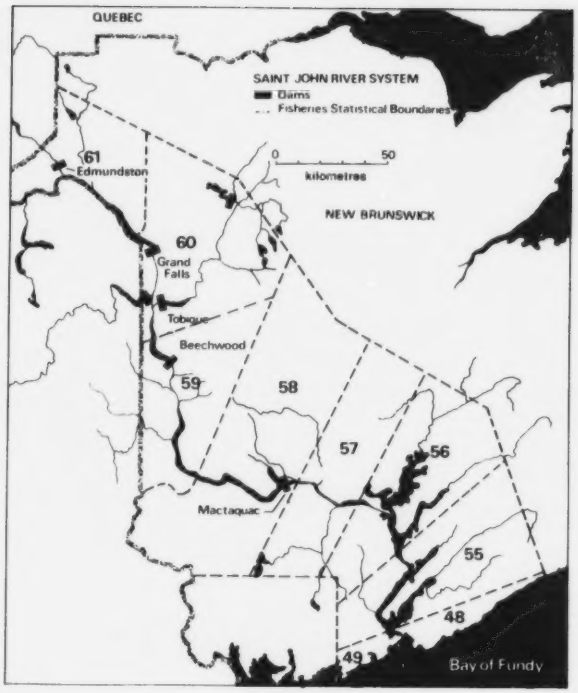

Figure 2. Fishery districts of the St. John River.

Fishery Districts (55, 56, 57) located downstream of the Mactaquac Dam, of which District 56 is the major producer (Figure 2).

Eel fishing occurs between May and November, with peak catches occurring at any time between June and October. There are no season restric-

Table 2. Commercial landings (tonnes) and value ($,000) of American eels from the Saint John River, New Brunswick, 1968-1979.

Year	District 55		District 56		District 57		Total	
	Weight	Value[a]	Weight	Value[a]	Weight	Value[a]	Weight	Value
1968	11	3	<1	-	1	1	13	4
1969	16	4	48	21	<1	-	64	25
1970	15	4	34	15	8	3	56	22
1971	11	6	40	20	14	6	64	32
1972	1	-	29	17	8	5	38	22
1973	8	3	17	10	5	2	30	16
1974	5	3	15	10	<1	-	20	13
1975	<1	-	37	33	28	12	50	45
1976	7	5	56	39	14	11	77	55
1977	30	33	49	48	21	19	100	100
1978	17	19	24	22	3	3	44	44
1979[b]	23	36	25	38	26	33	74	107
Mean	12.0	9.7	31.2	22.8	10.8	8.0	52.5	40.4

[a] dash (-) indicates value less than $1,000.

[b] preliminary figures

tions, nor restrictions on the number of gear units permitted, other than as decided by the local fishery officer. Both "yellow" and "silver" eels are fished indiscriminately since there is no premium for "silver" eels. "Yellow" eels are caught mainly in the spring, summer and late autumn, while "silver" eels are taken in the early autumn months.

The wide fluctuations evident in the annual catches within a District can be attributed to the combined effects of market demand and price, fishing effort and eel abundance.

During the 1960's, the American eel fishery was most active in District 55, less active in District 56 and almost inactive in District 57 (Table 2). During the 1970's, the situation changed, with District 56 becoming the most productive area and District 57 becoming a significant contributor to the total catch. From 1969 through 1971, fishing effort and catches were at high levels in all three Districts; then they declined during the mid-1970's to relatively low levels, before increasing again prior to their most recent decline.

The high catches of 1969-1971 (mean 62 metric tonnes) were associated with increased market demand and higher prices. Between 1969 and 1972, market prices increased from about 38.8 cents/kg to 58.4 cents/kg, then they declined in 1973, as did the catch. The fishing effort, as represented by the number of gear units licenced, declined from 217 to 88 gear units between 1970 and 1973, yet the catch per unit effort remained relatively constant (Table 3). Since the mean size of eels caught decreased and the larger eels became more scarce, it is suggested that overfishing was occurring, particularly in District 56 where several times as many gear units were fished as in the two other Districts combined. More recently, the market value of eels has reached nearly $1.00/kg, the number of licences issued has sharply increased, and the catch in all Districts is again declining as is the catch/unit effort. Between 1974 and 1979 the mean length of eels captured in Grand Lake of District 56 declined from 42.9 cm to 38.5 cm. Mean weights now average less than 100 g for eels from Grand Lake, but eels from a less intensively exploited region of the St. John River average over 140 g in weight and 44 cm in length. Overfishing is probably occurring now in all three Districts; certainly a reduction in or redeployment of fishing effort would be expected to improve the fishery.

In the past, the fishermen's practice has been to heavily fish an area and then move on to another area or reduce the number of traps set. When the catch or market outlook was not good, some fishermen might temporarily drop out of the fishery. But, with the high prices paid for eels in recent years, the tendency has been for more fishermen to enter the fishery and for established fishermen to fish more gear.

In summary, the increasing value of the American eel as an export product and the declining catches, in spite of increased fishing effort, has prompted a higher profile for the eel fishery in the Maritimes. Hopefully, the recent effort to rationalize one major eel fishery will prove effective and thereby spread to other fisheries with resultant improvement in catches and quality of fishery management.

Table 3. Number of eel licences issued and catch per unit of effort (CUE) in tonnes for Fishery Districts 55, 56 and 57 of the Saint John River, 1969-1979.

	District 55		District 56		District 57		Total	
Year	No. of licences[a]	CUE	No. of licences[a]	CUE	No. of licences[a]	CUE	No. of licences[a]	CUE
1969	29	0.55	25	1.92	0	0	54	1.19
1970	10	1.50	205	0.17	2	4.00	217	0.26
1971	26	0.42	141	0.28	21	0.67	188	0.34
1972	15	0.07	101	0.29	9	0.89	125	0.30
1973	8	1.00	70	0.24	10	0.50	88	0.34
1974	14	0.36	101	0.15	25	0.01	140	0.14
1975	12	0.04	52	0.71	59	0.47	123	0.41
1976	18	0.39	120[b]	0.47	65[b]	0.22	203	0.38
1977	12	2.50	114	0.43	70	0.30	196	0.57
1978	57	0.30	141	0.17	150	0.02	348	0.13
1979	199	0.12	287	0.09	325	0.08	811	0.09
Mean	36.4	0.659	123.4	0.447	66.9	0.651	226.6	0.372

[a] licences are required only for trap and fyke nets, not for eel pots

MARITIMES-DISCUSSION

1. The question of obtaining catch information data in the Maritimes was raised. Data are obtained by the "sales slip system" which was instituted some years ago by the federal fisheries service. Data are collected and submitted each month by fishery officers to the central collection point at Halifax. Obtaining a breakdown of these data (from individual fishery officers) is, at times, according to the speaker, a shortcoming of the system.

2. The speaker, in reply to a question on harvesting elvers, indicated that his directorate would recommend the controlled harvesting of elvers. No requests, however, have been received for elver fishing licences in recent years.

There was some discussion on the wisdom of elver fishing. Dr. C. L. Deelder indicated that elver fishing has not been detrimental to eel stocks in Europe. He stated that they are fished regularly and processed as a food product for export and for use in eel culture operations. Dr. C. Moriarty stated that in Ireland, elvers have been removed from river estuaries and released in the upper reaches of the same river for the past 20 years. He added that the program is expanding. Mr. W. J. Christie pointed out that Japanese workers indicated to him that they believed they had damaged their eel stocks by removing elvers for fish culture purposes.

The Chairman concluded from the pros and cons, that elver harvesting is another subject which requires more information.

PRINCE EDWARD ISLAND

THE EEL (*Anguilla rostrata*) FISHERY ON PRINCE EDWARD ISLAND

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In the early sixties, the American eel (*Anguilla rostrata*) fishery was identified as one of the possible areas for expansion in the inshore fisheries. Landings during this period were from 16-32 metric tonnes annually. Expansion of the fishery did occur in 1971 when landings reached an all time high of 337,478 kilograms. The resource was unable to support the heavy fishing pressure and landings have since diminished to the present level of about 90,720 kg. In 1978, the landed weight was 112,039 kg, having a value of $100,000. In 1979, landings were 81,648 kg with a value of $117,000.

Although the eel fishery is a relatively minor fishery, it ties in well with other estuarine fisheries. Most eel fishermen also are involved in harvesting one or more of the following: smelt, tomcod, oyster, silverside and quahaugs. The income from the eel fishery alone is not substantial; nevertheless. it does contribute to the income of 75 to 100 fishermen. The equipment involved includes a wooden boat, usually 5 metres in length and propelled by a 15-25 h.p. outboard, and anywhere from 5 to 25 eel traps.

EFFORT

In 1979, 216 fishermen were issued 2,995 permits for eel traps. The number of permits issued is not an accurate indicator of effort as some fishermen request permits even though they do not use them. This is due mainly to two reasons. Firstly, previous boom years have left many fishermen holding licences and equipment, but until stocks recover, they are not going to fish. Secondly, previous experience with government has shown that licencing restrictions can be implemented at any time, thus fishermen are encouraged to obtain every licence possible.

FISHING METHODS

Eels are harvested mostly by eel traps, with about 5% caught as a by-catch in the smelt fishery. Eel spearing in the winter and spring accounts for approximately 5% of the landed weight.

SEASONS

The season for eel traps opens on August 16 and ends November 30. Spearing is permitted all year; however, during the months of September, October, and November, using a light is not permitted.

BUYERS

There are five buyers of eels on P.E.I. presently sharing the market on a 54/20/16/7/3% ratio. The eels are frozen and shipped to European markets. The eels are sold by weight in the following categories:
255-340 grams (which average 55 cm)
340-454 grams (61 cm)
454 grams and above (65 cm)

ANNUAL STATISTICS

Year	Landings kg (x10^3)	Value ($,000)
1960	23	5.4
1961	18	4.2
1962	17	2.9
1963	16	3.6
1964	34	8.0
1965	49	12.1
1966	34	8.6
1967	62	15.8
1968	131	32.0
1969	195	43.0
1970	240	97.7
1971	351	194.1
1972	272	182.6
1973	157	105.2
1974	101	59.7
1975	103	68.6
1976	94	71.7
1977	100	80.8
1978	112	100.2
1979	82	117.0

CONSIDERATIONS FOR MANAGEMENT OF THE EEL FISHERY ON P.E.I.

The market outlook is encouraging, both for frozen and live eels. A strong market will lead to increased prices to fishermen, which in turn will lead to increased effort.

The resource is not unlimited. In the early seventies, tremendous fishing pressure resulted in increased landings, initially; however, the outcome has been a serious decline in landings in the last few years.

Speared eels usually command 5-7¢ less per kg than trapped eels. Although spearing does

not yield the best quality of fish, the number of fishermen involved in this fishery is very insignificant.

Presently there are no restrictions on the number of licences or number of traps.

The size of eels harvested is determined, at present, by the individual processor. Some processors accept eels 340 grams and above, while others purchase eels as low as 255 gm.

The actual number of permits issued for traps (2,995 in 1979) is not an accurate indicator of effort.

Fishermen realize that the resource will not withstand the heavy fishing pressure that existed in the early seventies; however, any changes in the regulations would be of concern to some fishermen.

Given a limited resource, the objective of a management plan for eels is to obtain as much as possible from the resource, provided the fishermen and processors can live with the management plan.

NEWFOUNDLAND

THE NEWFOUNDLAND EEL FISHERY[1]

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The Province of Newfoundland has exported American eels *(Anguilla rostrata)* periodically since 1930. Recent statistics show that the total yearly landing has increased, with greater participation in the fishery. Landings have increased steadily from 7380 kg (16,256 lbs.) in 1975 to 23,860 kg (52,555 lbs.) in 1979.

Through the years, various groups in the province have attempted to establish eel fisheries. Some of these have flourished for a few years, only to fade out as stocks declined. Exploratory surveys have been conducted in various rivers throughout the province to determine the availability of eel stocks.

In 1979, the Provincial Department of Fisheries initiated a program to aid the development of the eel fishery. This consisted of monitoring existing eel fishing operations, demonstrating fishing techniques and providing gear in "new areas" and locating new eel fishing areas.

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[1]The following is a very brief summary of Government of Newfoundland and Labrador, Department of Fisheries, Development Branch Report No. 10, entitled Newfoundland Eel Fishery Development, 1979. (C. Mullins, 1980).

AMERICAN EEL, *Anguilla rostrata*, - NEWFOUNDLAND REGION

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The commercial fishery for the American eel *(Anguilla rostrata)* in Newfoundland is limited to a few small operations along the north, south and west coasts of the island. There also has been limited activity on the east coast during the last few years. Boundaries of statistical fishing areas of insular Newfoundland are shown in Figure 1. Landings of American eel in the Newfoundland Region, for the years 1961-1980, are given in Table 1 and shown graphically in Figure 2 (for the whole region) and Figure 3 (by statistical area). There are no commercial eel fisheries along the Labrador coast, due to the limited distribution of eels in Labrador and lack of sufficient numbers to sustain a viable fishery. In 1979, the Provincial Department of Fisheries initiated a program to assess the status of the eel fishery in Newfoundland, with the intention of possibly expanding the fishery to other areas of the province (Mullins 1980). In 1981 the Bay d'Espoir Development Association, under the sponsorship of Canada Employment and Immigration, will be initiating a pilot project to determine the feasibility of catching, rearing and marketing Bay d'Espoir eels. This project will involve experimental fishing to assess the extent of the eel resource in the area, and the design and construction of

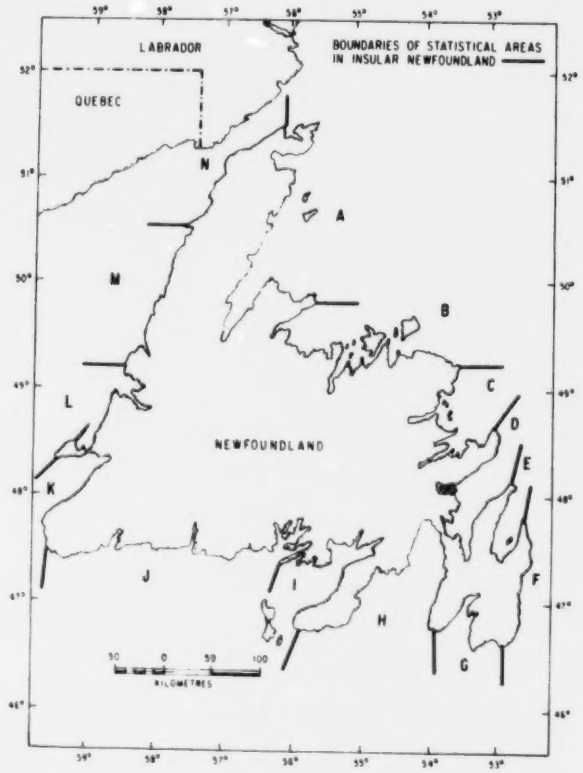

Figure 1. Boundaries of statistical fishing areas in insular Newfoundland.

Table 1. Commercial eel landings (metric tonnes) in insular Newfoundland for the years 1961-1980 by statistical area, as shown in Figure 1.

Area	1961	1962	1963	1964	1965	1966-70	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
A	-	-	-	-	-	-	-	-	-	-	-	3.1	6.2	0.3	0.4	0.81
B	-	-	-	-	-	-	-	-	-	-	-	1.5	0.5	-	-	0.284
C	-	-	0.2	1.3	-	-	-	-	-	-	-	-	-	-	-	0.45
D	-	12.5	8.8	-	-	-	-	4.0	-	<0.5	-	-	-	-	-	3.008
E	-	4.6	-	-	-	-	-	-	-	-	-	-	0.9	1.2	2.936	
F	-	-	-	-	-	-	-	-	-	-	-	-	2.821	-	-	2.821
G	-	3.4	3.0	-	-	1.0	-	-	-	-	-	-	-	-	2.1	2.423
H	-	1.8	14.8	3.7	2.4	-	-	-	-	-	-	2.1	-	-	-	-
I	-	1.2	10.2	7.0	0.9	-	-	-	-	-	-	-	-	-	-	-
J	-	-	-	1.0	-	4.0	17.0	5.0	19.0	7.1	6.2	-	-	-	0.011	
K	0.25	-	-	-	-	36.0	52.0	22.0	2.0	0.3	0.5	7.7	14.5	19.6	44.943	
L	-	-	-	-	-	-	10.0	-	-	-	-	-	-	0.1	0.114	
M	-	-	-	-	-	-	-	-	-	Inc.	-	-	-	-	25.539	
N	-	-	-	-	-	3.0	-	-	-	-	-	-	-	-	-	-
O	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.25	23.5	37.0	13.0	3.3	44.0	79.0	31.0	21.0	7.4	11.3	16.5	15.7	23.4	82.16	

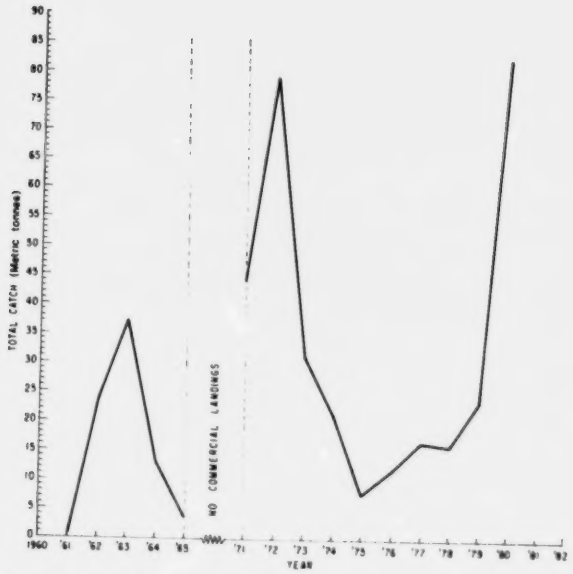

Figure 2. Commercial eel landings (tonnes) for insular Newfoundland for the years 1961-80.

a facility to hold and feed immature eels to determine whether rearing of eels is economically feasible in this environment. Depending upon the success of this part of the project, a market survey will be undertaken to determine preferences for eels and market sources. A contract has been awarded to a biological consultant to oversee the activities of the project.

One must have a licence to fish eels in Newfoundland. Under the Newfoundland Fishery Regulations, a person can fish for eels from August 15 to November 30 in inland waters with either eel pots or trap nets, providing the traps do not interfere with, or impede, the passage of any fish ascending inland waters to spawn. The use of spears to take or kill eels during the period November 1 to March 31 is permitted in such inland waters if specified in the licence. The regulations also state that "no person shall take by fishing or buy, sell or export from the Province any eel that is less than eight inches in length except as authorized by, and in accordance with, a licence".

Currently, there is no scientific research being conducted on the American eel in the Newfoundland Region. In 1976, the Department of Fisheries and Oceans initiated a two-year study to provide critical information on catching methods,

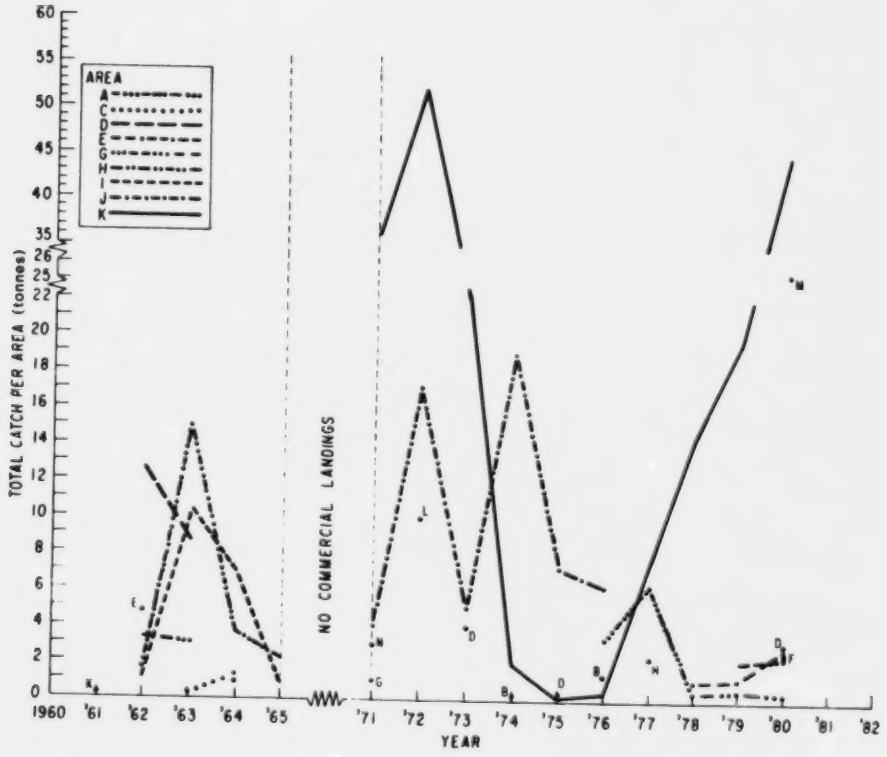

Figure 3. Commercial eel landings (tonnes) for insular Newfoundland by statistical area for the years 1961-80.

optimum fishing season, and management recommendations derived from the biology of the eel in Newfoundland waters.

The study involved tagging experiments to determine population estimates and movements of eels throughout two watersheds, one on the east and the other on the west coast of the province. Otoliths were removed for aging purposes and specimens were taken from each area for morphometric measurements and meristic counts to determine if there is more than one American eel stock in the Newfoundland Region. Standard biological measurements, length, weight and sex ratios were determined from a representative sample in each area. The data are to be incorporated into a Ph.D. thesis by C. Button at the University of Rhode Island, N.Y.

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NEW YORK

COMMERCIAL FISHING FOR EELS IN NEW YORK STATE

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INTRODUCTION

Fishing for American eels *(Anguilla rostrata)* in New York State is a tradition dating back many years. While the commercial harvesting of eels has never been a major industry, it does provide income to a moderate number of fishermen.

The fishery is divided into inland fishing, where commercial licences are required, and marine fishing, where no licencing is involved. Records for inland fisheries are derived from licenced fishermen, who are required to submit monthly reports. Records of marine landings are from a variety of sources, primarily fish dealers.

The fishery has been quite stable since 1960, with inland landings averaging 18,000 kg (40,000 lbs.) per year (Figure 1), and marine landings averaging 68,000 kg (150,000 lbs.) per year (Figure 2). The inland fishery is concentrated in Lake Ontario. No catch records are available for other inland waters except for number and type of gear: 12 weirs and 3 pots in the Delaware River and one pot each in Lake Champlain Canal, Seneca River and Silver Lake. It is estimated that the total catch from these waters is less than 2,300 kg (5,000 lbs.).

In Lake Ontario, eels were taken by 10 to 15 licenced fishermen. The number of marine eel fishermen is unknown.

COMMERCIAL LANDINGS

Commercial landings and dollar value are shown in Figures 1 and 2. In the opinion of those responsible for summarizing these data, the reported or computed landings are low. Inland landings reported by the fishermen are low because the majority of sales are on a cash basis. Marine landings are computed by contacts of known fish dealers. Individual sales are not included.

The price per kilogram fishermen received for their catch has increased steadily since 1960, more or less in keeping with the inflation rate: 33¢ in 1960, 48¢ in 1967, 55¢ in 1970, 88¢ in 1974 and 97¢ in 1977. In 1978, however, the price jumped to $1.58 per kg and then, in 1979, to $3.08 per kg.

METHODS OF CAPTURE

With the exception of incidental catches by eel weirs, pots, spears, and hook and line, the primary method of capture in inland waters (Lake Ontario) has been Oneida Lake style trap nets. The fishery occurs primarily in the spring, from ice out to May 15. In 1979, experimental permits were issued which allowed the use of electrofishing gear in specified areas. The method proved very successful, both from the fisherman's point of view and because the gear is ultra selective. Thirty-five days of effort resulted in the landing of 5,500 kg (12,000 lbs.) of eels

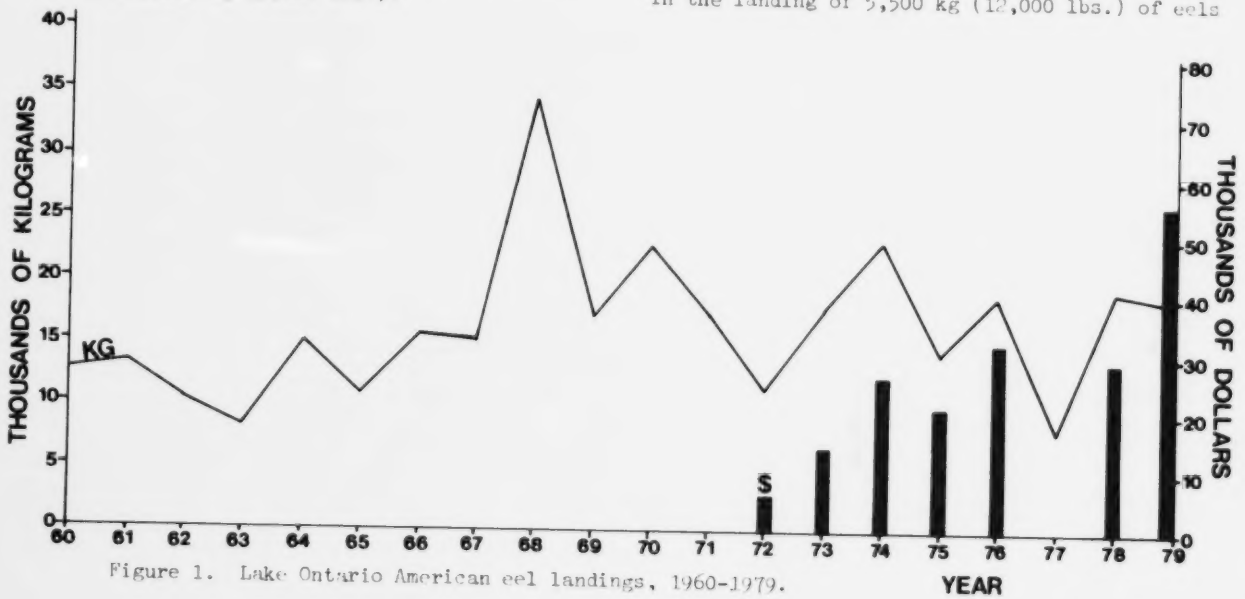

Figure 1. Lake Ontario American eel landings, 1960-1979.

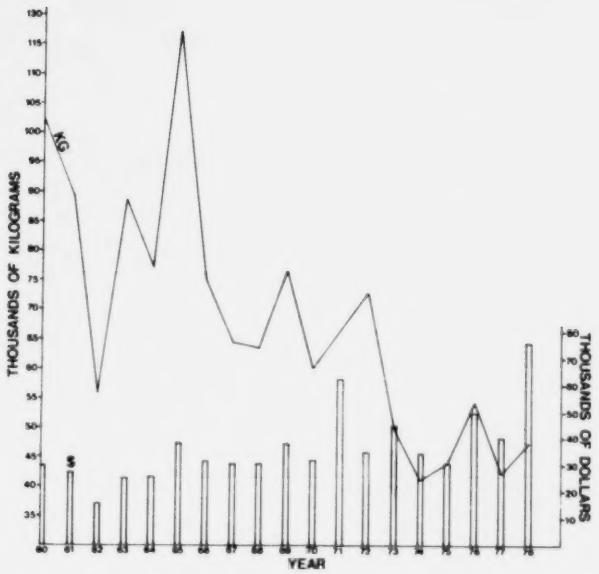

Figure 2. Marine district American eel landings, 1960-1978.

valued at $16,000, a gross income of $450 per effort. During the same period of time, six days of netting effort landed 400 kg (900 lbs.) of eels valued at $1,200 or $200 per effort.

More methods are utilized in the marine fishery. For any given year, about one-third of the catch is taken by each of three methods: pound nets, pots and traps, and spears. The latter is misleading because 90% or more of the catch reported under this category are taken by "combs", a rake-like device dragged behind a boat. Other gear types taking insignificant numbers of eel are gill nets, set lines and dip nets.

EFFECTS OF CONTAMINANTS ON COMMERCIAL FISHING

In September of 1976, the New York State Department of Environmental Conservation, in conjunction with the Department of Health, issued a ban on the possession and sale of eels taken from Lake Ontario and the Hudson River. The ban did not affect the marine fishery except for the tidal portion of the Hudson River. The restrictions were the result of PCB levels in eels exceeding the maximum tolerance level of 2 ppm: 50-75 ppm in Hudson River eels and 2.5 -4.5 ppm in Lake Ontario eels.

The effect of the ban on the marine fishery was minimal, as landings for 1975 included only 1,860 kg (4,100 lbs.) from the Hudson River. The Hudson River fishery for eels no longer exists.

In Lake Ontario, the ban resulted in no reported sales of eels in 1977, a loss of at least $35,000 to the fishermen and $210,000 to the economy of the area. The fishermen located foreign markets and petitioned D.E.C. to allow such sales. Early in 1978, the ban was modified to allow sales to foreign markets.

CURRENT MANAGEMENT

New York's eel management consists solely of maintaining records on eel harvest from Lake Ontario. Traditionally, New York fisheries managers considered eels as competitors to more desirable species. The construction of major barriers to eel migration was viewed as a benefit, which explains why Ontario took the lead in developing the eel ladder at the Moses-Saunders Power Dam on the St. Lawrence River.

With the expansion of the European eel market, our thinking has changed, not only as a result of the rapidly increased dollar value of eel (this came later), but also from concern for the well-being of this exceedingly interesting and biologically important fish species.

FUTURE OUTLOOK

New York is in the process of revamping its inland commercial fishing regulations and fee schedule. Part of the proposal includes a project to support and possibly expand commercial fishing. New York encourages continued experiments with electrofishing gear by commercial fishermen and anticipates formal licencing in 1980. Insofar as the species is concerned, New York will participate in any way possible to ensure the future well-being of the American eel.

NEW YORK - DISCUSSION

1. In answer to a question on electro-fishing boats, it was pointed out that two boats have operated under experimental licences. Apparently, there are two- and three-man boats operating, which are not restricted to quantity caught but are required to fish in specified areas.

2. Regarding electro-fishing and the capture of species other than eels, it was explained that the experimental licence specifies, "for the capture of eels only".

3. In reply to a question on details of electro-fishing gear, it was indicated that data are available from the New York Department of Environmental Conservation. Dr. E. Crossman of the Royal Ontario Museum described their

experience in electro-fishing muskellunge. He indicated that details of that work are available.

4. Regarding the economics of commercial electro-fishing gear, the speaker considered that costs were high. Nevertheless, he suggested that commercial fishermen could give a more practical assessment.

MASSACHUSETTS

MASSACHUSETTS EEL FISHERY SUMMARY REPORT

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The freshwater and marine resources of Massachusetts come under the management authority of two separate divisions, the Division of Fisheries and Wildlife and the Division of Marine Fisheries, respectively. Massachusetts General Laws relating to Marine Fisheries grant certain authority to the coastal towns to manage their American eel *(Anguilla rostrata)* resources. In 1978, state marine fisheries laws were amended by a clause restricting gear: eels may be taken only by nets, pots, spears, or angling. In addition, elvers or eels less than 4 inches (10.16 cm) may not be harvested unless for aquacultural purposes. (One such permit has been issued since 1978.)

Prior to 1981, Massachusetts freshwater regulations stipulated that eels could be fished in inland waters (defined as "upstream of the first bridge") only by rod and reel. In late 1980, the Division of Fisheries & Wildlife adopted rules and regulations for the commercial take of eels, limiting the number of licences to 15. Legal gear includes the use of wire or net pots only, with a minimum mesh size of 0.5 inches (1.27 cm) and a funnel opening not exceding 2.0 inches (5.08 cm).

Forty-eight coastal towns "control, regulate or prohibit the taking of eels".[1] In ten of the above towns, no permits and/or regulations are required to fish eels. Local authorities in five towns require only an eel permit or commercial shellfish licence. The remaining towns, with a few exceptions, "control and regulate" the fishery by means of gear restrictions. In most cases, this means a limit on the number of pots per fisherman. During the past two years (1978 and 1979) several towns amended the existing commercial eeling laws. One such town adopted emergency regulations (by closing a river and marsh area) to deal with dwindling eel catches. At least two Massachusetts towns increased permit fees for non-residents and/or added new gear restrictions to counter declining catches.

Massachusetts' commercial eel fishery is concentrated in the approximately 52 larger estuaries, embayments, coastal streams and saltwater ponds along the mainland and the two offshore islands of Nantucket and Marth's Vineyard.

Eel fishermen south of Boston are primarily part-time fishermen, concentrating their efforts in the spring and fall. On the north shore of the state (specifically the Merrimac River), the season extends from April to November. Baited wire eel pots/traps are used. Fishermen commonly set from 20 to 200 pots. Horseshoe crabs *(Limulus polyphemus)* are the most common bait. The demand for these crabs has caused fishermen to seek markets out-of-state, principally in Rhode Island. Fyke nets are allowed only with permission from both town and state marine fisheries authorities.

We have perceived an increased effort in the Massachusetts eel fishery over the past four to five years. Evidence of this is derived through personal communication with fishermen and catch data. Several estuaries that were fished by only a very few "traditional" fishermen ten years ago are now showing signs of this increased pressure - mainly in the form of the marketing of smaller eels (less than 1 lb. (454 gm)) and declining catch rates. Neither Massachusetts fishery agency has been active in the management of this resource until recently. The Division of Marine Fisheries' present interest is to monitor the fishery and improve landings statistics.

Given the life history of the American eel and the state's limited data base, increased management of the coastal eel fishery is premature. We believe that local control has been adequate; it has provided a means for more immediate reaction for initial management and still provides a more effective system for law enforcement.

MASSACHUSETTS - DISCUSSION

1. In reply to a question on the capture of elvers for eel culture purposes in Massachusetts, it was explained that the eel culture operator obtains the licence, not the fisherman.

[1]Chapter 130, Massachusetts General Laws.

MAINE

THE ATLANTIC EEL *(Anguilla rostrata)* FISHERY OF MAINE

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Augusta, Maine 04333

The Atlantic eel *(Anguilla rostrata)* fishery of Maine was considered so unimportant that landing data were not reported prior to 1898, or for several of the years between 1900 and 1916. Landings and values for the period prior to World War I are listed in Table 1.

Table 1. Landings and value of American eel from 1898 to 1916.

Year	Landings in Metric Tonnes	Value
1898	18.2	$ 4,019
1899	29.7	3,994
1900	60.3	4,847
1904	93.2	15,139
1905	97.1	15,855
1906	61.4	10,322
1907	74.5	13,335
1908	113.7	20,024
1909	135.1	22,963
1910	165.6	28,144
1911	167.9	29,698
1912	181.5	28,788
1913	124.2	24,119
1914	159.8	29,882
1916	135.8	26,482

The first reference to the fishery, other than a statistical summary, was a comment of the Commissioner in the Biennial Report of 1907-08 in which he stated: "This is one of the minor varieties to which very little attention is paid and of which about the same amount are caught each year in the same localities. The industry takes care of itself, and no general legislation seems to be necessary".

The next reference to the fishery was in 1911-12 when the Commissioner in office made the following observations: "Not many fishermen follow catching eels as a business. There are a few men, however, who make good wages. The most successful way is with traps, although there are comparatively large quantities of them caught with spears from boats, and also in the winter time with spears through the ice. Lincoln, Washington, Sagadahoc and Cumberland are the largest eel-producing counties in the State. The total value this year of the eel fishery was about $29,000".

No eel landings were reported from 1917 to 1944. Between 1945 and 1948, a total of 25.02 metric tonnes, with a landed value of $12,771.30 was reported. Reporting on a continuous basis did not begin until 1949. At this time, landings were differentiated by fishing areas (counties) (Figure 1), together with identification of catch months (Table 2).

The 1977 catch consisted of 69.7 tonnes of eels and 10 tonnes of elvers, with a value of $152,596 and $110,000 respectively.

In 1978, eel landings amounted to 53 tonnes, valued at $98,641; elver landings were 7.6 tonnes, valued at $63,251.

Of the 710.4 tonnes of eels harvested and identified by area from 1949 to 1977, 571.2 tonnes or 80% came from the eastern half of the Maine coast (Table 3). November and December were the principal catch months, with November being listed in 79% of the years and December in 71%. Only March and April have no reported landings.

In addition to the methods of capture listed by the commissioner in his 1911-12 biennial report, weirs and eel pots are extensively used.

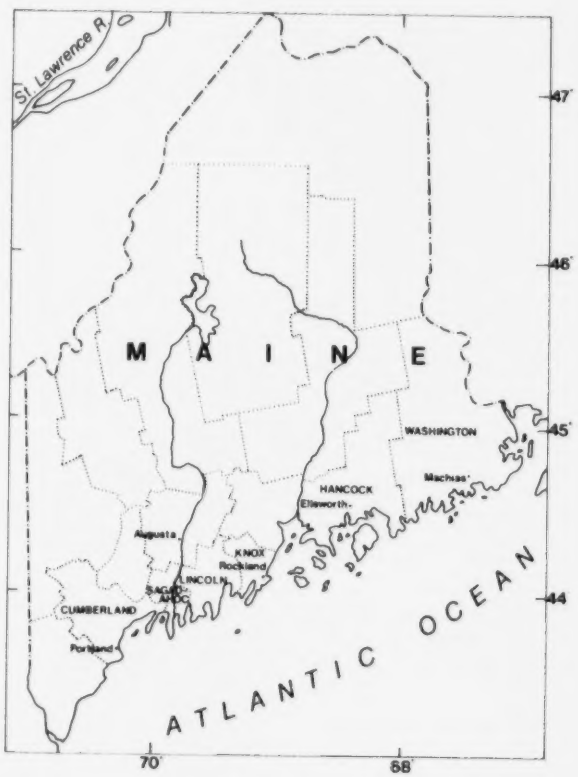

Figure 1. Fishing areas (counties) of Maine.

Table 2. Maine eel landings statistics (1949-1977).[a]

Year	Area	Landings in Metric Tonnes	Landed Value	Fishing Months
1949	Hancock	10.4	$ 4,580	February, May, June
	Sagadahoc	1.0	550	
	Washington	7.6	3,542	
		19.0	$ 8,672	
1950	Hancock	4.3	853	January, September,
	Knox	.1	40	October, November
	Washington	12.8	4,596	
		17.2	$ 5,489	
1951	Hancock	10.2	$ 4,606	
	Lincoln	.5	224	
	Sagadahoc	1.3	700	
	Washington	12.0	5,300	
		24.0	$ 10,830	
1952	Hancock	2.8	$ 1,284	July, August, October,
	Washington	16.2	7,754	November, December
		19.0	$ 9,038	
1953	Hancock	4.0	$ 1,781	January, May, June,
	Lincoln	2.4	505	July, August, Septem-
	Washington	12.1	5,559	ber, November, December
		18.5	$ 7,845	
1954	Hancock	3.9	$ 1,755	January, May, July,
	Lincoln	.6	105	August, September,
	Washington	.8	333	October, November,
		5.3	$ 2,193	December
1955	Hancock	5.2	$ 2,389	July, August, Septem-
	Lincoln	4.1	853	ber, October, December
	Washington	5.5	2,529	
		14.8	$ 5,771	
1956	Hancock	5.0	$ 2,220	October, December
	Lincoln	.4	71	
	Washington	7.8	3,434	
		13.2	$ 5,725	
1957	Hancock	2.7	$ 1,479	May, November,
	Knox	.1	50	December
	Lincoln	.3	124	
	Washington	5.8	2,369	
		8.9	$ 4,022	
1958	Hancock	3.4	$ 1,675	July, September,
	Lincoln	.3	100	October, November,
	Sagadahoc	1.2	182	December
	Washington	4.8	2,207	
		9.7	$ 4,164	

Table 2 continued on page 45

[a] Includes eels and elvers. Differentiation between eel and elver landings data began in 1977.

Table 2.(continued) Maine eel landings statistics (1949-1977).[a]

Year	Area	Landings in Metric Tonnes	Landed Value	Fishing Months
1959	Hancock	3.7	$ 1,768	July, August,
	Lincoln	.7	125	November, December
	Washington	3.3	1,470	
		7.7	$ 3,363	
1960	Total	13.8	$ 4,327	November, December
1961	Hancock	4.3	$ 2,288	September, November,
	Lincoln	.8	510	December
	Washington	9.5	4,637	
		14.6	$ 7,435	
1962	Hancock	6.0	$ 2,394	November
	Lincoln	.3	135	
	Washington	9.7	3,855	
		16.0	$ 6,384	
1963	Hancock	7.0	$ 2,939	October, December
	Lincoln	.2	65	
	Washington	9.6	4,231	
		16.8	$ 7,235	
1964	Hancock	4.1	$ 1,973	November, December
	Lincoln	.3	120	
	Washington	6.0	2,926	
		10.4	$ 5,019	
1965	Hancock	12.6	$ 6,094	December
	Lincoln	2.0	990	
	Washington	9.0	4,378	
		23.6	$11,462	
1966	Hancock	12.8	$ 5,650	November
	Lincoln	.8	340	
	Washington	8.5	3,750	
		22.1	$ 9,740	
1967	Hancock	14.0	$ 5,555	November, December
	Lincoln	.6	279	
	Washington	7.4	3,605	
		22.0	$ 9,439	
1968	Hancock	.4	$ 202	October, November
	Washington	29.4	14,046	
		29.8	$14,248	
1969	Hancock	2.5	$ 1,155	November
	Washington	14.7	6,809	
		17.2	$ 7,964	
1970	Hancock	1.7	$ 965	December
	Washington	15.3	7,723	
		17.0	$ 8,688	
1971	Hancock	5.6	$ 3,486	November
	Sagadahoc	3.3	2,016	
	Washington	15.7	9,702	
		24.6	$15,204	

Table 2 continued on page 46

[a]Includes eels and elvers. Differentiation between eel and elver landings data began in 1977.

Table 2.(continued) Maine eel landings statistics (1949-1977).[a]

Year	Area	Landings in Metric Tonnes	Landed Value	Fishing Months
1972	Cumberland	.2	$ 137	November
	Lincoln	.8	641	
	Washington	30.8	23,800	
		31.8	$24,578	
1973	Hancock	13.8	$12,146	November, December
	Knox	.1	120	
	Sagadahoc	1.2	875	
	Washington	19.3	16,414	
		34.4	$29,555	
1974	Cumberland	1.4	$ 1,350	October, November,
	Hancock	11.7	10,310	December
	Sagadahoc	.6	500	
	Washington	22.5	20,158	
		36.2	$32,318	
1975	Hancock	20.6	$24,935	November, December
	Lincoln	6.8	7,247	
	Sagadahoc	23.2	26,506	
	Washington	19.7	23,692	
		70.3	$82,380	
1976	Hancock	15.1	$16,650	November, December
	Knox	.5	720	
	Lincoln	18.9	19,336	
	Sagadahoc	21.9	22,591	
	Washington	30.2	34,368	
		86.6	$93,665	
1977	Cumberland	5.9	$ 98,025	November, December
	Hancock	4.8	49,215	
	Lincoln	36.4	51,720	
	Washington	32.6	63,632	
		79.7	$262,596	

[a]Includes eels and elvers. Differentiation between eel and elver landings data began in 1977.

Table 3. 1949-1977 Eel landings by area.

County	Landings in Metric Tonnes	% of Total
Cumberland	7.5	1.1
Hancock	192.6	27.1
Knox	.8	.1
Lincoln	77.2	10.9
Sagadahoc	53.7	7.6
Washington	378.6	53.3
	710.4	

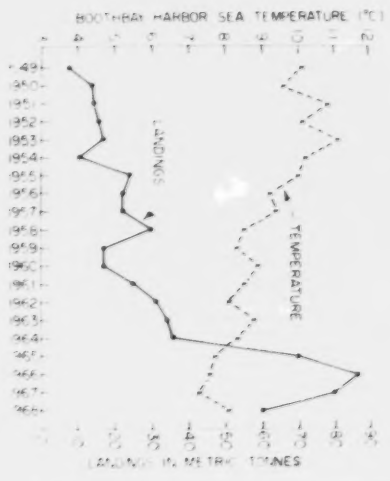

Figure 2. A comparison of sea temperatures with eel landings ten years later.

Fluctuations in the landings of the Maine eel fishery are attributed to two factors: 1) abundance fluctuations associated with sea temperature cycles, and 2) a relatively low level of demand until the early 1970's.

There is a highly significant correlation between sea temperatures, as measured at Boothbay Harbor, Maine, and eel landings ten years later (Figure 2). In relation to other commercial fisheries of the State, the eel fishery is one of 17 which are inversely correlated with sea temperature.[1] Optimum temperature as measured at Boothbay Harbor is approximately $7.7^{\circ} \pm 0.4^{\circ}C$. Other species whose landings are highly significantly correlated with sea temperature represent 97% of the volume and 98% of the value of all Maine marine and estuarine landings.

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1 "Influence of sea temperature cycles on the abundance and availability of marine and estuarine species of commerce. Robert L. Dow. OCEANS 81 Conference Record, Vol. 2, IEEE Publication Number 81CH1685-7.

NORTH CAROLINA

THE AMERICAN EEL *(Anguilla rostrata)* FISHERY IN THE INLAND WATERS OF NORTH CAROLINA

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The American eel *(Anguilla rostrata)* fishery in North Carolina is relatively minor compared to many of the other finfish and shellfish fisheries in the state. Nevertheless, the harvest of eels from North Carolina waters has increased dramatically since 1970. Generally, less than 45.4 tonnes (100,000 lbs.) of eels were landed per year prior to 1970, whereas landings in the years since often have doubled this figure. This sudden increase in eel harvest reflects a dramatic increase in the average price for eels, stimulated by a highly profitable market for the export of eels to Europe and the Orient for human consumnption. Prior to this, eels were used in North Carolina primarily as bait. Increased eel harvest also may be attributed, in part, to eeling promotional programs presented by the University of North Carolina Sea Grant and the Migrant and Seasonal Farm Workers Association. These agencies have expended much effort and money to stimulate the eeling industry of North Carolina in recent years.

The waters of North Carolina fall into three classifications: coastal, inland, and joint. The North Carolina Division of Marine Fisheries has jurisdiction and authority over all fishing activities in coastal waters and commercial fishing activities in joint waters. The North Carolina Wildlife Resources Commission has jurisdiction and authority over all fishing activities in inland waters and sport fishing activities in joint waters.

Eels are considered to be rough or nongame fish by the North Carolina Wildlife Resources Commission, and thus are harvested in the inland waters of North Carolina under regulations dealing with nongame fish. Subadult harvestable size eels are normally caught with traps or pots in inland waters. Traps and pots are classified as special devices, along with bows and arrows, seines, gill nets, dip nets, bow nets, reels, gigs, spear guns, baskets, and automobile tires. Special device fishing licences are available from the Wildlife Resources Commission at prices ranging from $3.00 for resident-personal use to $25.00 for nonresident-nonpersonal use. Special device fishing licences are not specific for type of gear or species of fish, therefore it is impossible to accurately estimate the amount of effort expended in fishing for eels in inland waters. Special device fishing regulations vary from county to county. Nevertheless, most counties in eastern North Carolina are open to fishing with traps and pots year-round in selected or all inland public waters.

In recent years, a fishery for "glass eels", or the transporant juvenile elvers, has developed in North Carolina in response to a market spurred by eel culture programs in the Orient. Glass eels are captured in the wild, shipped to the Orient, and reared to marketable size. These elvers are harvested with seines, fyke nets, or dip nets during the early spring months in areas where fresh water enters brackish water. This fishery occurs in both inland and joint waters. The elver fishery appears to have been relatively inactive during the past two years.

Records specifically on the harvest of eels and/or elvers from inland waters are not kept. Estimates of the harvest from inland waters would be very difficult to make because of the non-specificity of special device licences and because special device fishermen are not required to keep any records of their catch. The bulk of the eels harvested from inland waters, however, are probably sold to commercial fish dealers and are included in the total landings figures published by the National Marine Fisheries Service and presented by the North Carolina Division of Marine Fisheries reports.

The following are specific questions and problems dealing with the American eel and its fishery, towards which research should be directed.

(1) Specialized techniques for randomly sampling wild eel populations should be developed and standardized in order for the sampling results of the various agencies to be comparable.

(2) The maximum sustained yield (MSY) or optimum sustained yield (OSY) should be determined to prevent overexploitation of eel stocks. The eel fishery in North Carolina may be approaching or exceeding MSY in some areas.

(3) How do high eel populations affect inland sport fish populations? Studies have indicated that eels feed heavily, at times, on gamefish eggs. Are eels serious predators on inland gamefish populations?

(4) How does the eel fishery affect other fish populations? Does the incidental capture of other fish species in eel traps adversely affect gamefish populations? What particular designs of eel traps would minimize incidental capture of other fish species?

(5) What is the age structure of the eel population in North Carolina? What is the growth rate of eels?

(6) What is the sex ratio of the eel population in North Carolina?

(7) How much effort is expended in the eel fishery in both inland and commercial fish-

ing waters and what is the harvest of eels from inland waters of North Carolina?

(8) The mesh size that will catch and retain only the eels of a harvestable size should be determined to prevent overfishing and excessive damage to undersize eels.

(9) The reproductive biology of eels should be thoroughly studied.

(10) What are the effects of the elver fishery on future eel stocks?

NORTH CAROLINA

THE AMERICAN EEL *(Anguilla rostrata)* FISHERY IN THE COMMERCIAL WATERS OF NORTH CAROLINA

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The eel fishery in North Carolina was considered minor until 1972. From 1950 to 1971, eel landings ranged from 7,000 to 79,000 kg in weight (16,000 to 174,000 lbs.) and from $1,000 to $27,000 (US) in value. The catch was utilized primarily for bait. Since 1972, the average price for eel has risen dramatically to a high of $1.85 per kilogram or 84¢ per pound (US) in 1979 (Table 1). The increase in price can be directly attributed to utilization of American eels in the European markets for human consumption. The North Carolina Sea Grant College Program greatly assisted fishermen by providing information on how to catch, hold and sell eels for the export market.

The bulk of the eel landings were from the northeastern coastal region of North Carolina; however, with the increased value of eels, the fishery is rapidly expanding into the southernmost area of North Carolina. In the northeast region, Currituck Sound has received the most concentrated effort. Conversations with Currituck fishermen revealed that the number of fishermen in the area at least doubled during 1979. To maintain their catch at previous levels, fishermen had to increase the number of pots they were fishing two-to four-fold. These statements may be indicative of the harvest surpassing the maximum sustainable yield for the area.

Table 1. Landings of American Eel *(Anguilla rostrata)* in North Carolina from 1950 to 1979.

Year	Weight		Value	Ave. Price ($US)	
	Kilograms[a]	Pounds	($US)	per kg[a]	per lb.
1950	78,996	174,000	21,000	0.26	0.12
1951	14,528	32,000	2,000	0.13	0.06
1952	17,252	38,000	1,000	0.07	0.03
1953	23,608	52,000	2,000	0.09	0.04
1954	16,798	37,000	2,000	0.11	0.05
1955	20,430	45,000	3,000	0.15	0.07
1956	51,302	113,000	5,000	0.09	0.04
1957	28,602	63,000	3,000	0.11	0.05
1958	39,498	87,000	3,000	0.07	0.03
1959	44,946	99,000	4,000	0.09	0.04
1960	29,964	66,000	3,000	0.11	0.05
1961	25,878	57,000	2,000	0.09	0.04
1962	19,522	43,000	2,000	0.11	0.05
1963	17,706	39,000	2,000	0.11	0.05
1964	24,062	53,000	3,000	0.13	0.06
1965	18,160	40,000	2,000	0.11	0.05
1966	24,516	54,000	2,000	0.09	0.04
1967	10,442	23,000	1,000	0.09	0.04
1968	10,896	24,000	1,000	0.09	0.04
1969	8,172	18,000	1,000	0.13	0.06
1970	7,264	16,000	1,000	0.13	0.06
1971	75,818	167,000	27,000	0.35	0.16
1972	34,958	77,000	42,000	1.23	0.56
1973	60,836	134,000	56,000	0.92	0.42
1974	205,208	452,000	188,000	0.93	0.42
1975	108,052	238,000	84,000	0.77	0.35
1976	231,578	510,083	234,422	1.01	0.46
1977	117,266	258,296	112,227	0.95	0.43
1978	315,805	695,605	472,252	1.50	0.68
1979	422,238	930,039	781,233	1.85	0.84

[a]Metric values were obtained by a direct conversion of the Imperial units.

Eel pots are the primary gear used to harvest eels in North Carolina. At present, there are no regulations on mesh size. Nevertheless, eel buyers are putting pressure on fishermen to use a mesh size of at least one inch by one-half inch (2.54 cm by 1.27 cm), by refusing to buy eels less than one quarter pound (113.5 gm).

The elver fishery in North Carolina has been very sporadic. No information is available at this time. Fishermen have not harvested elvers since 1977.

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GEORGIA

DEVELOPMENT OF THE AMERICAN EEL *(Anguilla rostrata)* FISHERY IN GEORGIA

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The University of Georgia Sea Grant Program, in cooperation with the Georgia Marine Extension Service, is initiating a study of the potential for an expanded American eel *(Anguilla rostrata)* fishery in Georgia's waters. The fishery is not monitored at present, but is thought to be relatively small; less than a dozen fishermen are involved. This number is expected to increase sharply in the near future as a result of recent changes in state fishing regulations that previously limited eel fishing to brackish and marine waters.

The investigation will involve assessment of stock size and distribution, age and growth, sex ratios, and diel and seasonal movements in selected rivers. *In situ* observations will focus on diel activity cycles, home range characteristics of individuals, and eel behaviour with respect to various types of eel pots. Mark/recapture and catch census data will provide information on the effect of fishing intensity on a largely unexploited resource. Emphasis also will be placed on determining the impact of an expanded eel fishery on other commercially important fishes, particularly catfishes. Efforts will be made towards developing an eel trap that minimizes catfish capture. The study will provide initial data that should form the framework for future management decisions concerning American eel resources in Georgia.

DEVELOPMENT OF THE FISHERY FOR AMERICAN EELS *(Anguilla rostrata)* in Georgia[1]

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The legal fishery for the yellow, or resident, phase of the American eel *(Anguilla rostrata)* in Georgia effectively opened in March 1980. Prior to that time, eel fishing had been restricted to brackish waters. The best estimates of the size of the fishery in 1979, based on commercial landing statistics, indicate that approximately a dozen fishermen captured 3900 kg of eels, valued at $7500. At this level, eel fishing ranked as the 13th largest fishery in the state.

The trap fishery had been restricted because of likely conflict between eel fishermen and other commercial and sports interests. Conflict centered around baited eel traps and the potential for catching other fishes, such as catfishes, in the traps. Studies in South Carolina in 1979, however, indicated that the incidental catch of commercially important species was minimal. As a consequence, the Georgia Department of Natural Resources agreed to open the eel fishery in freshwaters for one year (March 1980 to March 1981) on a provisional basis. The decision to leave the fishery open after the first year would involve consideration of the impact of eel fishing on catfishes and on other users of Georgia's waterways.

In September 1980, the Georgia Sea Grant Program and Marine Extension Service initiated a study of the American eel fishery in the Altamaha River, Georgia. This study was aimed at providing information on the incidental catch problem, as well as obtaining basic information on the size and status of eel populations in the river. The results on incidental catch suggest that the catch per unit effort for eels is 42 times greater than for catfish, on a weight basis, and 115 times greater on an economic basis. These results concur with those of South Carolina and also with those of the Georgia Department of Natural Resources.

Our findings, with respect to population characteristics, indicate that eels in Georgia may grow more rapidly (up to 15 mm mo^{-1}) and mature earlier (after six to eight years) when compared to more northerly populations. In addition, estuarine eels, although smaller, apparently grow more rapidly and mature earlier than freshwater individuals in the same river. This growth difference may result from the high secondary production levels that characterize the extensive salt marshes of coastal Georgia. If these trends are confirmed, they would suggest that the eel populations in Georgia turn over more rapidly than in northern areas. As a consequence, the yellow eel fishery in Georgia may be able to sustain fishing pressure at a greater level than has been found for some populations at higher latitudes.

The future for eel fishing in Georgia is promising. At the end of the provisional year of fishing, few instances of conflict between eel fishermen and other fisheries had been recorded. The studies on incidental catch suggested little reason for concern. The provisional fishery was also economically successful, employing 50 fishermen with reported catches of 50,000 kg, valued at over $100,000. This moved eel fishing up to the fourth largest fishery in the state, exceeded only by shrimp, crabs, and shad. Consequently, the trap fishery has been legalized on a permanent basis and is expected to continue to grow as long as catches and ex-vessel prices remain high.

Possible barriers to this continued growth are problems typically associated with yellow eel fisheries, namely seasonality and potential overexploitation. In anticipation of these possible problems, Sea Grant has funded an additional year of study to begin a preliminary investigation of the times and places of movement and feasibility of capture of elvers and silver eels. Other aspects of this ongoing study include assessment of stock size and distribution, age and growth, sex ratios, and diel and seasonal movements in the Altamaha and two other rivers. *In situ* observations are focusing on diel activity cycles, home range characteristics, and eel behavior with respect to various types of eel traps. These studies will provide information on the effect of fishing intensity on a previously unexploited resource, and will aid in the formulation of management decisions.

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[1]Editor's note:
This paper is not part of the 1980 Eel Conference proceedings. It is an update on the development of Georgia's eel fishery since the Conference. It has been included for the interest of researchers and fisheries managers.

THE EUROPEAN EEL SITUATION

THE EUROPEAN EEL *(Anguilla anguilla)* FISHERY

Dr. C. L. Deelder[1]
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The speaker outlined the extensive range of the European eel *(Anguilla anguilla)*. The area includes waters of Iceland, Norway, around the Baltic, Denmark, Holland, the United Kingdom, Ireland, the south coast of France, Portugal, Spain, around the Mediterranean to Israel, Egypt and along the north coast of Morroco. Elvers migrate naturally up many major European rivers, such as the Rhine and Elbe, as far as Switzerland and Czechoslovakia. The European eel did not occur naturally in the Black Sea. It has been established, however, through introductions in the Danube River by Russia and Hungary. Elvers are readily available from England and France for introductions.

Dr. Deelder referred to the knowledge of and use of eels as a food product by Egyptians and other civilizations in ancient times.

Methods of capture vary throughout the range of the European eel. Some old techniques are still in use in Europe; for example, spears and hoop nets are employed. Where eels are found in great concentrations, such as in Egypt, unbaited hooks on lines are used. On the other hand, extremely big pound nets are used in the Baltic.

Trawling for eels was a common method practiced in Holland's former Zuider Zee. Nevertheless, with the increased efficiency of powered boats, it was considered to have an adverse effect on eel stocks and was banned.

Silver eels migrating in the fall in stagnant water, for example where there are outlets to the sea from inland bodies of water, are captured by stationary gear. This method has been practiced for centuries in lagoons in the Venice area. In more recent times, the technique has been employed in areas between the former Zuider Zee and the North Sea, where sluices, which are closed at night when the silver eels are migrating, permit a successful fishery with fyke nets for the silver eels seeking an escape. Small canals also may be barred by nets, but trash that collects in these nets tends to create a serious problem.

Dr. Deelder went on to describe silver eel fishing techniques in running water. The most important of these is a very large net, 30 to 40 metres long, fished in major European rivers such as the Rhine. These nets are anchored on and operated from barges in the river. Hundreds of these nets are located, one behind the other, in rivers such as the Rhine during the fall seaward migration of silver eels. Because downstream nets catch as many eels as those located upstream, it is assumed that silver eels have the ability to avoid nets and other obstacles. Another method still in use is the placing of horizontal gratings in cataracts.

Dr. Deelder indicated that in spite of heavy exploitation of silver eels throughout Europe over the years, stocks appear to be in no immediate danger. (It would appear that the escapement of silver eels is aided by the fact that their seaward migration frequently takes place at the time of freshets or floods).[2]

Reference was made to various types of eel management operations. For example, in Hungary and Germany "eel free" lakes above waterfalls are regularly stocked with elvers. Adult eels produced in these lakes are harvested by gratings in the outlets. Dr. Deelder explained that large quantities of elvers are caught in many areas of Europe. Some are used in eel culture projects, others are processed and used directly as a food product. He quoted recent statistics which indicated that more than 1500 tonnes of elvers caught in southern France were shipped to Spain and Mexico for human consumption. He concluded that availability of elvers is not a problem in Europe.

Regarding the management of eel stocks, Dr. Deelder indicated that for various reasons determination of the stock size is practically impossible in Europe. One principal reason is that fishermen are reluctant to provide catch information. He suggested that the best fishing practice is to concentrate on harvesting silver eels and to allow elvers free passage to inland waters. Reference was made to one example of overfishing in the Ijsselmeer (Netherlands) when the trawl fishery changed from sail to motorized boats. Trawling was later banned.

Dr. Deelder stated that fresh and salt water diseases are known and that when these reach serious proportions, they have been known to cause the total loss of stocks, for example, in the Baltic area. At present, a disease problem has been identified in the Ijsselmeer (Netherlands). Nothing can be done about these outbreaks. It was explained that the Rhine and many of its tributaries are heavily polluted with PCB's and other chemicals and, as a result, eels taken from these waters are seriously contaminated.

The transport and storage of eels is an old practice. As far back as the 17th century, eels

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[1] Dr. Deelder's presentation was taped. "Audience noise" on the tapes, however, made it impossible to hear the entire presentation clearly. This summary was prepared by the Secretary from the tapes and several sets of notes. Therefore, the Secretary assumes responsibility for any errors and inaccuracies in this summary.

[2] Secretary's note.

were shipped to London in the holds of Dutch ships. With today's knowledge and modern transportation systems, there is relatively little difficulty in transporting live silver eels. Stress during the capture and handling of eels, however, does result in some delayed mortality which shows up during transport.

Dr. Deelder referred to a breakthrough in eel culture, in 1979, by Italian workers. Production was raised from near zero to one million kilograms. He added that if you can produce one million kilograms, you can very easily produce greater quantities. Dr. Deelder explained that cultured eels using modern techniques are of excellent and consistent quality. It seems likely that regulated culture programs will become increasingly popular in the future. Another plus for cultured eels is that there is virtually no mortality during their transport. Dr. Deelder also stated that cultured male eels may be considerably larger in size, compared to wild male eels. This is believed to be due to the food provided to cultured eels.

Dr. Deelder indicated that the future for eel culture is particularly good in southern Europe (e.g. Italy) where there are good supplies of elvers, abundant growing pond areas, plenty of labour, suitable warm temperatures and many pollution-free water sources. He suggested that eel culture in southern Europe (Italy, France, Spain, Portugal and Greece) will surpass commercial wild eel fishery production and therefore is one of the major problems facing eel fisheries in Europe and North America.

Dr. Deelder concluded his presentation with comments on the development of international scientific eel study groups in Europe.

Some years ago, the European Inland Fisheries Advisory Commission (EIFAC) became interested in the initiation of an eel study program. A short time later, the International Council for the Exploration of the Seas (ICES) also commenced an eel study group. The two groups combined to form the ICES/EIFAC Working Group on Eels, under the chairmanship of Dr. Deelder. (Dr. Moriarty is also a representative of this group.) Dr. Deelder referred to some of the projects under consideration by the Working Group. Age determination, which is recognized as one of the basic problems associated with eel studies, is of particular concern to the Working Group. Dr. Deelder expressed the hope that a standardized procedure in the use of otoliths would be developed, and elaborated on some details of the techniques being used. He stressed the importance of age determination to eel studies, especially to stock assessment.

EXPERIENCES IN EEL MANAGEMENT IN EUROPE

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INTRODUCTION

The first references to eel in the scientific literature are those of Aristotle, who flourished in the 4th century B.C. and set down the basic facts of the life of the freshwater eel, in particular the arrival of the elvers and the downstream migration of silver eels. No doubt, informed interest in eels went back a great deal further in time. Seven thousand years ago the earliest known inhabitants in Ireland settled on the banks of the River Bann where it leaves Lough Neagh. To this day, this area is the most important eel fishery in the country. It is tempting to believe that these early inhabitants were a community of eel fishermen.

After Aristotle, the most significant contribution to knowledge of the eel was that of Johannes Schmidt who discovered a breeding ground of American and European freshwater eels. He put forward the remarkable theory that both species breed in this region and in no other place, and that the European eel had a larval life of two and a half years. Many points of this theory have been questioned but for all practical purposes, it may be taken as factual. One cannot reasonably doubt that a great many eels of both species breed in the Sargasso Sea, that immense numbers of their larvae metamorphose off the coasts of Europe and North America and that the glass-eels migrate into coastal waters. To update things a little, there was a European expedition to the Sargasso in February, 1979, and a preliminary report by Tesch indicates that blood protein analyses of the youngest larvae strongly suggest the existence of two species. That expedition, like all previous ones, failed to catch any spawning eels but it did add a certain precision to the failure. They calculated that the chances against capture were 99.92%.

Since Schmidt's major paper was published, a great number of people have written about eels. In Europe, the last ten years have seen a literature explosion which dates back to Dr. Deelder's "Synopsis" published by FAO in 1970. In 1971, papers on eel fishing methods presented at a European Inland Fisheries Advisory Commission (EIFAC) "Consultation" held in Hamburg were published (McGrath 1971). F-W Tesch published a very detailed monograph in German, in 1973, and this has been translated and revised to include work published in 1976 (Tesch 1977). Tesch provides an invaluable bibliography and the English translation of his book is an essential for all eel specialists. My own eel book (Moriarty 1978) is more modest and I think might fairly be described as for fishery people rather than purely for eel people. There are two recent publications on eel farming and eel fishing (Forest 1976; Usui 1974). Last year, the principal papers presented to the ICES[1]/EIFAC eel conference in Helsinki were published and give an invaluable outline of the main work which has been done since the recent books were published (Thurow 1979).

In this paper, I am taking the eel very strictly from the point of view of biological management. It begins by giving a brief outline of the salient facts of the life of the European eel as far as they impinge directly on management of the stocks. The second part of the paper gives an account of methods for studying eel. By and large, they are simple methods and will lead only to approximations. The eel is an individualistic beast and an intransigent subject for research. In the present state of knowledge, it cannot be made to fit in with conventional population modelling. The suggestions made, therefore, are directed mainly towards amassing data which will be of value over a long term, rather than providing immediate solutions to problems which themselves are not fully appreciated.

THE EUROPEAN EEL

Glass eels arrive in coastal waters in autumn and, in Ireland, may be found on the seashore as early as November. Migration into freshwater begins when the temperature reaches about 9°C. There also seems to be a considerable degree of influence by the tide. Peak runs of glass eels may be expected when high tide occurs after sunset. In Ireland, glass eels usually begin to enter the larger rivers in April or May and the run may continue at a high level as late as August. Recent information has suggested that in the case of small streams, which perhaps are quickly heated by a few warm early spring days, the immigration may take place in March and may be completed before the run has even begun in the larger rivers.

The extent of glass eel migration varies greatly. In Holland and Germany, glass eels are found as far as 150 km inland. On the other hand, in one case in Ireland, the large scale migration of glass eels has ceased within 15 km of the salt water boundary. The differences may be related to the topography on the rivers: the continental rivers are long and flow through fairly level country while the Irish ones, in general, have rapids and pools close to their mouths.

Migrating glass eels are considered, by Dr.

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[1]International Council for the Exploration of the Seas.

Deelder, to maintain their positions in a river close to the bank, by the aid of their lateral line organs. In an unobstructed river, this brings them upstream without any problems, but the presence of a dam or canal lock may seriously upset their sense of direction. In some cases, glass eels prefer to follow a small trickle of water rather than attempt to swim past rapids. This makes capture at waterfalls a relatively simple matter.

Migration upstream continues for many years of the life of the European eel. Specimens of 30 to 40 cm length, and ages up to ten years, are captured in elver passes at dams. Nevertheless, the great majority of elvers caught at such traps are much smaller and younger. This observation may be taken to indicate that the urge to migrate in this way decreases with age and size, but the possibility that the type of ladder in use becomes less and less attractive to eels of larger sizes must be considered. There can be no doubt that small eels, particularly those of 1+ and 2+ ages, find it physically easier to enter an eel ladder than would larger specimens.

Migration of larger eels takes place regularly. In upstream lakes on Irish river systems, eels of less than 40 cm length are extremely rare, while larger specimens may be plentiful. Such a stock can only develop as a result of active migration by large eels.

In the lower reaches of rivers, and in estuaries, small yellow eels preponderate and large proportions of these are found to be males. In the higher reaches of rivers, populations are usually less dense than in the lower reaches and female eels become more frequent, sometimes to the exclusion of males. There are significant exceptions to this rule and, in Ireland and elsewhere, there are populations of eels in estuaries where females are present in substantial numbers and may even outnumber the males. When elvers are planted in upstream waters from which male eels were formerly absent, a population of male eels normally develops. Many eel specialists, perhaps the majority, hold that the sex of eels is determined to some extent by the density of the population, dense populations favouring the production of males. I cannot say that I am yet convinced by the arguments and I have an open mind on whether or not the sex is fully determined genetically.

European eels become silver when they have reached a length of more than 30 cm. Females seldom become silver at less than 45 cm and males seldom attain lengths of more than 45 cm. That is all that can be said with certainty about the cause of metamorphosis. It is probably safe to go a little further and say that the majority of males migrate at lengths between 35 and 40 cm and females commonly attain to between 60 and 70 cm. Eels of more than one metre length are rare in Europe, both in exploited and unexploited fisheries. The ages of silver eels are very variable and it seems that silvering is a function of size rather than a function of age. In general, fast-growing eels migrate much earlier than do slow-growing ones but even this is far from being an inviolable rule. The eels of the Shannon System in Ireland are slow-growing and mostly attain a lenth of 60 to 70 cm while those of the neighbouring Corrib System grow at about the same rate but seldom grow to more than 60 cm. It is possible that the diet of the yellow eel influences the size at migration.

Eels grow at varying rates. On physiological grounds, Jan and Inge Boetius, in 1967, established that the optimum temperature for metabolism of the European eel was 25°C to 26°C. In southern parts of the range, where these temperatures regularly occur for some months in summer, growth is rapid provided there is adequate food. Female eels can attain lengths of 60 to 70 cm in four to six years and males presumably even sooner. Nevertheless, there are many large populations of eels which thrive without ever living at temperatures of more than 20°C. In these cases, growth to 60 cm seldom, if ever, takes less than 8 years and frequently requires a period of the order of 15 to 20 years. Increase in length of the order of 2 or 3 cm a year seems to be common in northern climates and has been confirmed by tagging.

Yellow eels, in general, are nocturnal animals, retiring to burrows or to dense cover in daylight. They are also strongly dependent on temperature, becoming noticeably less active when the temperature falls below 11°C in autumn and remaining inconspicuous until the temperature reaches 9°C or 10°C in spring. In estuaries, it seems that the influence of the tide may over-ride the effect of daylight and eels are regularly caught on bait from harbour walls in the daytime. Possibly the fact that estuarine water is more or less muddy, contributes to the anomaly. Bright moonlight appears to inhibit activity, at least in clear rivers, though its influence is less noticeable in lakes and in tidal water. In bright sunny weather, however, eels do appear in the open, possibly simply enjoying the warmth.

Silver eel migration is virtually confined to the hours of darkness, apparently with a peak of activity within the first two or three hours after sunset. When the number of eels migrating is very large, however, passage down a river may continue throughout the night. The silver eels, when travelling in small numbers, may stay close to the river bed, but when the numbers are large, movement takes place at all levels of the water column. Silver eels which meet an obstruction apparently tend to swim over it, while yellow eels will follow a barrier for some distance. Nets for silver eels, therefore, are usually set so that the guiding wall stands out above the surface of the water. The peaks of migration of silver eels are associated with stormy weather, high water levels and avoidance of full moon. There are many exceptions, particularly when water conditions have been unsuitable for a long period. In these cases, a peak may coincide

with the full moon if a flood occurs.

EEL STUDY

LARVAE:

Deelder and Tesch demonstrated in a series of cruises that the abundance of larvae in offshore waters varied greatly from year to year. While the general pattern of migration of the larvae has been mapped, on the basis of studies undertaken over many years, there is a lack of information on a regular basis. Annual sampling of chosen areas, to yield data on relative abundance and length frequencies, would establish a base for information on the fluctuations of supplies of larvae. At present, there is no evidence of inadequate recruitment at the larval stage. Nevertheless, it is not possible now to assess the normal extent of variations in numbers of larvae and there is little hope of being able to do so until a regular sampling program is initiated.

GLASS EELS:

Fluctuations in the numbers of glass eels are well known in Europe, where glass eels have been exploited commercially, both for consumption and for stocking. If population modelling is ever to become possible, it will be necessary to have data on the level of recruitment which, for practical purposes, may be taken as the size of the glass eel immigration. In any case, the relative size of glass eel migration from year to year is an essential factor in long term studies.

The chances of establishing the absolute size of the glass eel entry to a large river are remote. Nevertheless, in the early part of the season, it is possible to capture the eels by dip net as they migrate close to the bank. This is the technique used in the River Severn in England. A long-handled net is used in the Severn; but a short-handled net, shaped rather like a tennis racket, was used in the River Feale in Ireland. Dip-netting ceases to be effective when pigmentation develops. Effort can be standardized so that it becomes possible to measure a catch in weight per scoop of the net. The number of hours during which the glass eels travel throughout the season may be recorded to give a measure of the duration of the run. The most significant physical variables are date, temperature, moon's phase, time of sunset and time of high tide.

Natural rapids and artificial dams offer possibilities of capturing and recording the entire recruitment of glass eels to a river system. The "low-head" trap (Figure 1) has been installed close to the bottom of a salmon ladder at Parteen, on the river Shannon, and appears to divert a large proportion of the migrating glass eels away from the salmon pass. Where possible, such traps should be installed on both sides of the river.

The most important measurement of the glass eel is the bulk weight, the number per kg, so that a good estimate may be made of the numbers being moved. Maturity stages (the accepted classification is given in Tesch (1977)), myomere counts and lengths are all of interest. Recent myomere counts of glass eels in Denmark, by Jan Boetius, revealed the presence of quite a few specimens which could be classified as *Anguilla rostrata* on traditional grounds. Maturity, as shown by development of pigmentation, can vary between populations in adjacent river estuaries and, of course, it changes within populations with time. Since the behaviour of the young eels changes according to maturity stage, this information may be significant in stock assessments. Length frequencies may be revealing in studying long-term changes of larval behaviour.

For bulk weighing the simplest treatment is to allow the water to drain off a sample of glass eels held in a dipnet. Precision could be added by taking samples of constant volume and allowing the water to drain for a specified time but I am not aware of this being done in practice. A repeatable method of collecting glass eels for length measurement should be adopted. I anaesthetize the sample with chlorbutol and store them in 70% alcohol. It is most important to take care not to stretch the specimens on the measuring board. Measurement to the nearest mm downward is adequate to produce useful length frequencies.

ELVERS:

Elver in this context implies a young eel, fully pigmented, in the course of migration upstream. The elver stage, therefore, may begin at 0+ (taking the glass eel as 0) and continues at least up till 10 years and perhaps for very much longer. Using this rather wide sense of the term, age determination becomes interesting, in addition to length frequency measurements. The nylon-tuft ladder attracts large numbers of 1+ and 2+ elvers and decreasing numbers of larger specimens. Length frequencies change throughout the season and should therefore be measured at regular intervals, perhaps monthly. For the same reason, bulk weighing should be carried out frequently if an accurate assessment of stocking rates is required. In my experience, only one such weighing is made in a season. For length measurements, I use a measuring board with a V-cross section which straightens out an anaesthetized eel. I have always used the anaesthetic chlorbutol which acts within a few minutes and from which specimens recover rapidly without ill effects. Ingenious electro-narcotising measuring boards have been devised but they seem to me to be expensive and to have a much higher risk of failure than the simple use of anaesthetic . At least one designer of such an instrument recommended that the eels should be roughly sorted according to size before being subjected

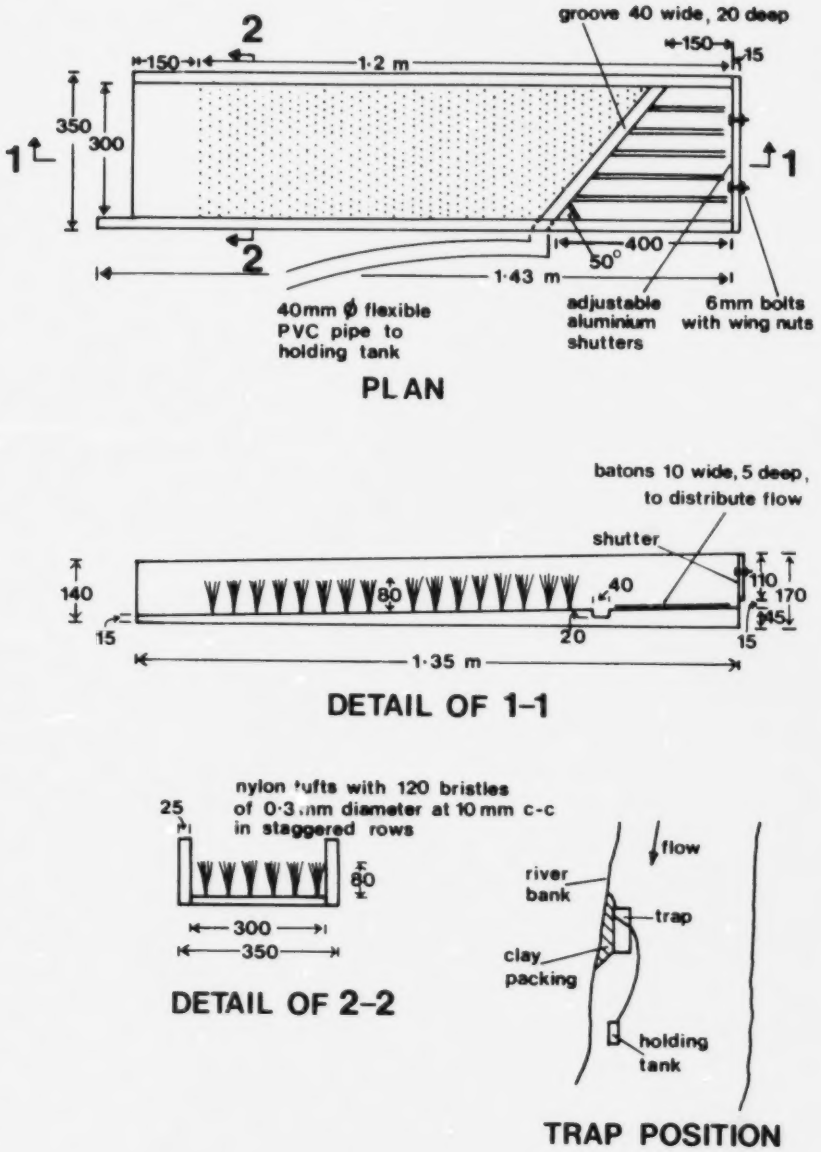


Figure 1. The low head eel trap. (Dimensions in mm, except where shown otherwise.) Adapted from O'Leary in EIFAC Technical Paper 14 (1971).

to the treatment and this alone would make the technique unnecessarily tedious. About ten grams of chlorbutol stirred into 2 litres of water will immobilize between fifty and one hundred eels at a time.

YELLOW EELS:

Yellow eels constitute the feeding and more or less sedentary stage of the species. Therefore, they overlap with elvers to an unknown degree. Elvers do migrate throughout the season, but it does seem likely that many individuals, even quite small ones, frequently adopt a habitat and remain in it for many years. Last year, in a river, we recovered a specimen which had been tagged in the same spot four years previously. Conversely, I have tagged hundreds of eels in one bay of a large lake and never had a recovery.

There are two good methods of sampling yellow eels. Electrical fishing in streams results in the capture of considerable numbers of eels of all sizes. It is the only satisfactory means, that I know of, for collecting good samples of eels of less than about 30 cm. It seems likely, however, that eels which are resting in burrows, or have sought refuge in them when disturbed by the fishing team, will not be induced to swim

out of the burrows by conventional gear. This could give very misleading results when attempts are being made to compare populations by catch per unit effort. A habitat with poor cover might yield a much higher catch than one with good cover. I might mention that I once saw a German fisherman operating his homemade electrofishing equipment. It consisted simply of a punt containing a number of lead-acid batteries in series, generating 200 or 300 volts. It worked very well, capturing many eels in water which a few minutes previously had failed to yield any to a much more sophisticated apparatus using a petrol-driven generator and giving a pulsed current. Given a situation where the batteries can be charged overnight, without having to be removed from the punt, this apparatus seems to me to deserve further investigation.

The gear which I have used consistently over the past fifteen years is the summer fyke net or "eelcouple" (Figure 2). This is easy to operate, works well in rivers and lakes, and gives good results in water up to 30 metres deep which is nearly the deepest that occurs in Ireland. A further advantage is that it is standard gear for professional fishermen and I am a strong believer in the value of using conventional equipment in investigations of this kind. The usual cod-end mesh is about 20 mm stretched. This retains all eels of more than about 40 cm long and collects substantial numbers of specimens from 30 to 40 cm. Specimens of less than 30 cm can easily escape through the mesh, but we discovered that a much finer mesh was no more successful in catching small eels. The fyke seems to make good catches over most kinds of substrate, including very uneven ground where the leader is frequently held off the bottom by stones or weed. Possibly under these conditions, there is a greater degree of escapement than on level ground.

Figure 2. Summer fyke-net train.

So there is no serious problem in obtaining samples of eels. To collect representative samples of eel populations under repeatable conditions is quite another matter. In the following section, I will give an outline of the principal known variables.

DATE:

Yellow eel activity is so limited in cold water that there is little point in beginning exploration work until the temperature reaches about 9°C. In my experience, it takes at least one month after hibernation to bring eels to their full degree of summer activity. Furthermore, it seems likely that there are periods during the summer when migration takes place. Therefore, it is essential, when attempting to compare stocks between years, that sampling takes place at the same time each year. The phase of the moon may also influence catch per unit effort and, ideally, sampling dates should be adjusted to coincide with a particular phase.

TEMPERATURE:

Periods of low temperature during the summer are likely to reduce the activity of eels. Also, it is possible that activity in general is lower in cool summers than in warm ones. This may have no influence in electrical sampling but could be an important factor in using passive gear such as the fyke net.

WATER DEPTH:

In lakes of varying depths, I found that the most productive regions were those of about 2 to 3 metres. This is also a convenient depth for operating the fyke net. Eels are usually much more scarce in water of one metre than in 2 metres and, therefore, conditions in the shallows are not necessarily typical of the general situation. Unusual changes in water level should be taken into consideration. I had one case when abnormal lowering of a lake apparently caused the eels to move far away from the shore, so that they were absent even from their accustomed depth of 2 metres.

SUBSTRATE:

The fyke net probably works most efficiently on surfaces of fairly level mud, where the sole rope can be in contact with the bottom along its entire length. Nevertheless, it also catches plenty of eels on all kinds of rough substrates, where there are large stones, where there is deeply fissured limestone or where dense growth of vegetation prevents the net from settling. Even when substrate conditions appear to be similar, great differences in catch may occur within relatively small areas. In one case, I consistently caught more than twice as many eels to the south of a small island than to the east, the island was only 500 metres long and the two grounds were within one km of each other.

UNIT EFFORT:

Unit of effort is rather difficult to define for electrical fishing. A selected length of stream fished a given number of times is a possibility. Using a fyke net in freshwater, the simplest unit is one net fished overnight. If one or more nets become seriously twisted, it is better to ignore their catches since there is no way of telling at what time the twisting took place.

The cod-end mesh size and the length of the leader are the most important parameters. Exact height of the net and length of the trap do not seem to affect the catch.

RELATIVE POPULATION DENSITY:

Weight per unit of effort can be measured quickly and is often the only figure available from professional fishermen. It means rather little on account of the great range of sizes likely to be present. The numbers of eel per unit of effort may be used to give an indication of the stock size, provided some preliminary work has been done to calibrate the gear. In Ireland, we now have adequate data from a wide variety of conditions to enable us to make a preliminary assessment of the productivity of a waterbody. Such a situation can develop in a small country where one worker over the years collects the information, personally. In a large country, the same can be done, provided all such data are circulated efficiently. The next stage in stock assessment, having gathered the physical data and taken a sample, depends on examining the individual specimens.

LENGTH FREQUENCIES:

Number per unit effort is better than weight per unit effort, but still leaves a very large gap in easily measured data. The length frequency of a sample, even of quite a small sample, is much more revealing. In Irish conditions, using a cod-end mesh of 20 or 24 mm (it does not seem to make much difference which), a sample of 100 specimens is adequate to give a preliminary indication of the nature of a population. In an unexploited population which derives from a good recruitment and includes a large proportion of relatively young specimens, more than 50% will measure less than 40 cm; whereas, if fewer than 50% are less than 40 cm, there are indications of poor recruitment resulting from slow migration upstream. Since eels migrate upstream very slowly, increasing proportions of large eels are expected as you move upstream. This is much more distinct when there are lakes close to the mouth of the river. In at least one case in Ireland, the most downstream lake effectively holds all the males and the next lake, only 80 km further on, has no males. Even within relatively small lakes, populations of large and small eels may be found in different parts. Therefore, it is essential to engage in extensive sampling when exploring new ground.

If all the physical variables I have mentioned are taken into account, I believe that much valuable information can be collected simply on the basis of catch per unit effort and length frequencies, if sampling can take place on a regular basis over a number of years. I emphasize this because it may be all the research effort that a fishery institution may be able to devote to eels in a situation where other species are of greater importance. The next stages, essential to more sophisticated work, call for full-time effort, at least in their early stages.

AGE DETERMINATION:

The scales of eels carry well-defined growth rings; however, scales do not begin to develop until the eel is about six years old. Therefore, they have seldom been used in age determination since Ehrenbaum and Marukawa, in 1913, established otolith-reading as the most satisfactory basis. Otoliths can be very beautifully sectioned, etched in acid and either examined by eye or passed through a light beam to give a graphical record of the form of the growth rings. I prefer the cruder, but more rapid method, of burning the otoliths in a bunsen flame and breaking them in two. Both methods reveal that, in some cases, there are very strongly defined rings which can reasonably be taken to be annual rings. Unfortunately, in many other cases, there are plenty of secondary rings, and I believe that at present, there is no certain method of identifying a growth check caused by winter as opposed to one resulting from a period of starvation in summer.

You can, therefore, make approximate determinations of the ages of all specimens in a sample of eels and exact determinations in some specimens. Even the exactly determined specimens will show a great range of lengths for any given year class and the range will be greater for the remainder. It is essential that all specimens be considered, since rejection of the uncertain readings will be rejection of the specimens which did not grow at a regular speed. These specimens probably have had lower growth rates than those which showed regular growth.

Crude though they are, the existing age determinations do yield very interesting results. In Ireland, we found that within an area only 100 km square, there were three distinct populations of eels in relatively rich water: one fast growing, early-maturing; one slow-growing, early-maturing and one slow-growing, late-maturing. Information of this kind is vital in considering plans for elver stocking if resources are limited and the most suitable waters are to be selected.

FOOD:

Eels swallow their prey whole and digest it rather slowly. I am not inclined to accept the possibility that invertebrates, such as lumbricid worms, are digested so quickly that they cannot be traced. My general opinion, therefore, is that stomach-analysis gives a reliable indication of the prey of eels. The food of eels is so variable that it is essential to carry out extensive sampling before coming to any conclusions. Within a single lake, we have found regional variations and variations from month to month; both

of which may be expected. A more disconcerting discovery was an apparent variation in diet between years over the same substrate. I believe, however, that it is possible to correlate different feeding regimes with different growth rates and ages at maturity. A second function of the food analysis is to try to determine the extent of predation or competition with other species. In this context I think it is important to remember that salmoniform fish are living at their optimal temperature, while eels in northern countries are subsisting well below theirs. It is, therefore, likely that eels are at a considerable disadvantage compared with the salmoniforms.

SEX:

Female gonads become recognizable in field specimens after a length of about 35 cm has been attained. Male gonads are much more difficult to distinguish. Sometimes, in relatively large individuals, the distinctive sausage-like structure may be seen; but, in a large number of cases, the gonads of male eels less than 40 cm are no more than fine tubes in which definite structures cannot be discerned. It is important to make sure that fatty tissue is not confused with the female gonad. Microscopic sectioning of specimens of 30 cm and longer can distinguish the sexes. It would certainly be interesting to be able to determine the proportions of the sexes of yellow eels in many populations; but, at present, this represents a labour-intensive operation of doubtful value.

TAGGING:

There is general agreement that tag loss by eels is high. A paper by Jundersen, in Thurow (1979), gives a very useful account of comparison between a number of methods, concluding that an internal stainless steel tag with a streamer attached had a good longevity, with recoveries after four years being reported. I have had some success with tags attached by a loop of stainless steel wire, which have been recovered up to one year later, and with Floy tags, which have lasted four years to date and which will probably continue to be returned. Both types were attached just in front of the dorsal fin. Tesch has had success in using internal stainless steel tags over a period of one year.

SILVER EELS:

I have great respect for the silver eel's ability to detect a possible trap. I began to develop this when a simple device was inserted in the drainage channel of an area of reclaimed land. The only possible way of escape for silver eels was through the trap and in about one season out of ten, eels were caught by the thousand. Few were caught in the intervening periods and I believe that the migrating eels made an overland escape in preference to entering the trap. The complexity of the traps shown in Figures 3 and 4 pay tribute to the eel's ability to escape. Fishermen consider it essential to

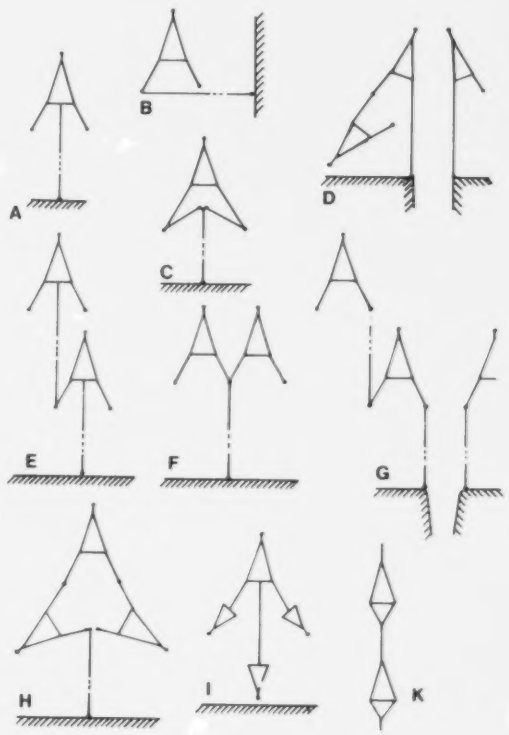
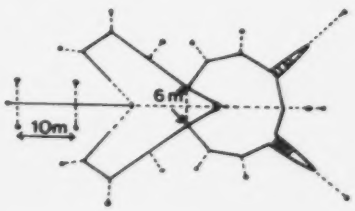


Figure 3. Systems of traps for eelfishing. FIFAC Technical Paper 14 (1971).



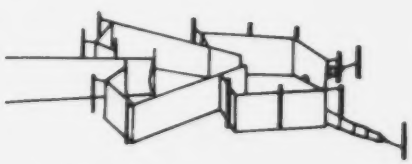


Figure 4. Baltic pound net.

provide a maze for silver eels, while yellow eel traps may be relatively simple. It is possible that where the only exit to an eel-bearing water is over a waterfall, and a trap can be built to take all the water flowing through it, a complete catch of silver eels may be made. In all other cases, substantial numbers of silver eels avoid the trapping devices. The proportion that escapes will vary according to the weather and the only certain fact is that the variation cannot be measured at present. All that can be calculated from the yield of a silver eel fishery is a minimum yield for the water body upstream.

As in the case of yellow eels, all the physical variables must be recorded, and observations on wind speed and direction should also be made. All traditional fishermen know that the best catches are made under particular conditions of wind and water flow.

Length frequencies vary through the season, with a tendency for the smaller specimens to migrate earlier in the year. Therefore, observations should be made at least once a month. Males can be distinguished from females by length, but it is desirable to dissect samples, periodically. In one case in Ireland, no fewer than 41% of the females measured less than the generally accepted length of 45 cm. Regular monitoring of length frequencies of silver eels provides the first indications of the success of stocking with elvers in cases where the natural population consisted only of females.

Age determination of silver eels is interesting, but must be treated with caution. The silver eel migration represents a gathering of individuals from many parts of a system of lakes or rivers. In any one part, there will be great variation of ages and, when the whole system is considered, it becomes very difficult to assess the significance of an age distribution. Silver eel studies of this kind must always be backed up by yellow eel sampling upstream.

Tagging of silver eels is an obvious way of checking the efficiency of trapping barrages and of measuring the rate of movement downstream. The simple approach is to collect silver eels from a trap, tag them and bring them upstream again. This results in the recapture of many. It also shows that the operation may upset the migration of some individuals so that they do not resume their journey until the following year. Tracking silver eels with acoustic tags has had some very interesting results to date and I believe that the techniques should be applied to the very important problem of improving methods of capture.

STOCK ASSESSMENT:

Under this heading comes population modelling. At the present, I am inclined to take a dismissive attitude to any classical approach to this subject. A population model which is capable of being used for practical purposes, for example to make a recommendation for total allowable catch or for a size limit, depends on having a large body of reliable data. In particular, modelling works very well in cases such as the herring, whose stocks have been studied for more than half a century. It grows rapidly and at a reasonably uniform rate within a population. Above all, its otoliths show very distinct growth rings.

Very few eel populations have been studied so intensively for so long a period. We know that growth is far from uniform. We know that ages cannot, at present, be determined accurately. All the papers which I have seen attempting to fit an eel population to a model make at least one major assumption which I know to be untenable. The sort of statement that appears is "assuming that the rate of recruitment is constant". We know for certain that the rate of recruitment is not constant.

I do not mean to belittle the value of developing population models. It is a very valuable aim and one which should be pursued where time and financial resources permit. What is important for practical purposes is to read very carefully any paper which attempts to establish a model for eel population and make quite sure that it keeps to facts and reasonable assumptions throughout.

What is needed at present for eel stock assessment is a large body of information on as many populations as possible. Eel recruitment will vary from year to year. Therefore, a system for monitoring glass eel or elver migrations must be developed. Catches of yellow eels will vary. Regular records on total effort, catch per unit and length frequencies will, in time, provide a basis for decisions on the significance of the variations. Silver eel runs will rise and fall. Again, catch per unit effort and length frequencies alone will provide a useful body of information.

There are two sources of information on eel stocks. First is the honest fisherman. The species is rare, but should not be ignored. Periodic sampling of professional catches, in circumstances where total effort and total catch are known, provide one of the least expensive and most valuable sources of regular data.

The second source is, undoubtedly, the better, though more expensive in scientific manpower. This is to establish stations where sampling under fully controlled conditions can take place at regular intervals over a long period. The amount of data which can be obtained from this kind of exercise depends naturally on the amount of time which can be made available. It is vital, in such a case, to be sure that it is possible to continue the series of observations over periods of the order of ten or twenty years or more. Most species of fish of commercial interest complete their life cycles in a few years. The eel does not. Therefore, the only way to develop a meaningful management program is to ensure that experiments can run for long periods. This is why I emphasize the need to collect simple data, such as catch per unit effort and length frequencies.

Of course, there is a need for much more sophisticated work, including, for a start, age determinations and food analyses of extensive samples. Work of this level necessitates full time attention by experienced scientists. The problem with eels is that because there are so many more variables than in most other commercial fish, the results of intensive work in one region cannot necessarily be extrapolated to another.

EEL MANAGEMENT:

The management of eel fisheries has been in progress in the Adriatic Sea for centuries. At Comaccio, near Venice, there are about 80,000 hectares of lagoons with warm water where sluices are operated to control the escape of silver eels and to admit elvers. Transportation of glass eels in Europe has been in progress at least since the early years of the present century, when the Germans established a fishery on the River Severn in England to collect stock for planting in Germany. More recently, especially following the development of hydro-electric dams on many of the major rivers, elver transplanting has become a regular part of eel management. The accepted rates of stocking vary from country to country and it is certain that the optimum rate for any particular watercourse is not yet know.

Examples of stocking rates and yields per thousand hectares are:

	Stocking (kg)	Yield (tonnes)
Poland	20	3
Russia	65	
Ireland	115	20

A detailed account of elver stocking in Europe was published in 1979 by Hakan Wickstrom in Sweden.

Storage and transport of small eels is relatively simple. They survive well in salmon-rearing tanks and can be transported out of water for periods of twenty-four hours or more, provided they are kept cool and moist.

CONCLUSION

The most important single factor in eel management is the slow growth rate. In practice this means that you do not expect any results from an undertaking for ten years or more. When experiments have to be conducted on this time scale, it is essential that the initial planning includes the possibility of changes of personnel. This makes the orderly recording of observations and regular summarizing of results of more than ordinary importance. This is also why I emphasize the need to work on collecting data which can be accurately recorded by relatively unskilled and inexperienced workers. To make a quick summary, I consider that priority should be given to the following items; they are listed in ascending order of effort required:

1. Capture and transport of known quantities of young eels to inland waters,

2. Regular monitoring of quantities and length frequencies of eels in commercial catches,

3. Establishment of annual sampling programs in waters where operations extending over a minimum of 10 years may be ensured,

4. Extensive surveys of yellow eel populations with particular reference to growth and feeding,

5. Study of eel behaviour with particular reference to migration,

6. Marine plankton studies to establish extent and causes of fluctuations in numbers of larvae.

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DEVELOPMENT OF TWO EEL *Anguilla anguilla* FISHERIES IN IRELAND

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INTRODUCTION

This paper describes two programs for controlled fisheries. The River Shannon has a catchment of about one-third of the area of Ireland and is potentially the greatest source of eels in the country. The presence of a hydro-electric dam and a large lake near the mouth of the river have inhibited the migration of eels to most of the rivers and lakes upstream. Since 1959, the Electricity Supply Board, which owns the entire fishery, has been carrying out a program of stocking with elvers. Fishing for yellow eels is forbidden. The scale of the second study described is very much smaller. The fishery is in the South Sloblands Channel, an artificial coastal lagoon of 100 hectares. Its interest lies in the fact that it is privately owned and fishing was monitored from 1970 to 1975.

Growth of the eels was relatively fast in the South Sloblands and a period of five years was sufficient to repopulate the area after a season of intensive fishing. Growth is considerably slower in the Shannon Lakes and it has taken fifteen years from the first stocking for a clear effect to be shown. In view of the extremely long times involved in such operations in cool climates, close study of the conditions and accurate monitoring of the results is essential so that other schemes may be effectively planned from the outset.

RIVER SHANNON

The freshwater eel is widely distributed throughout Ireland, occurring in all major rivers and lakes. Traditional methods of fishing provided an adequate return to fishermen and fishery owners and no active measures were taken to manage the fisheries. In 1928,

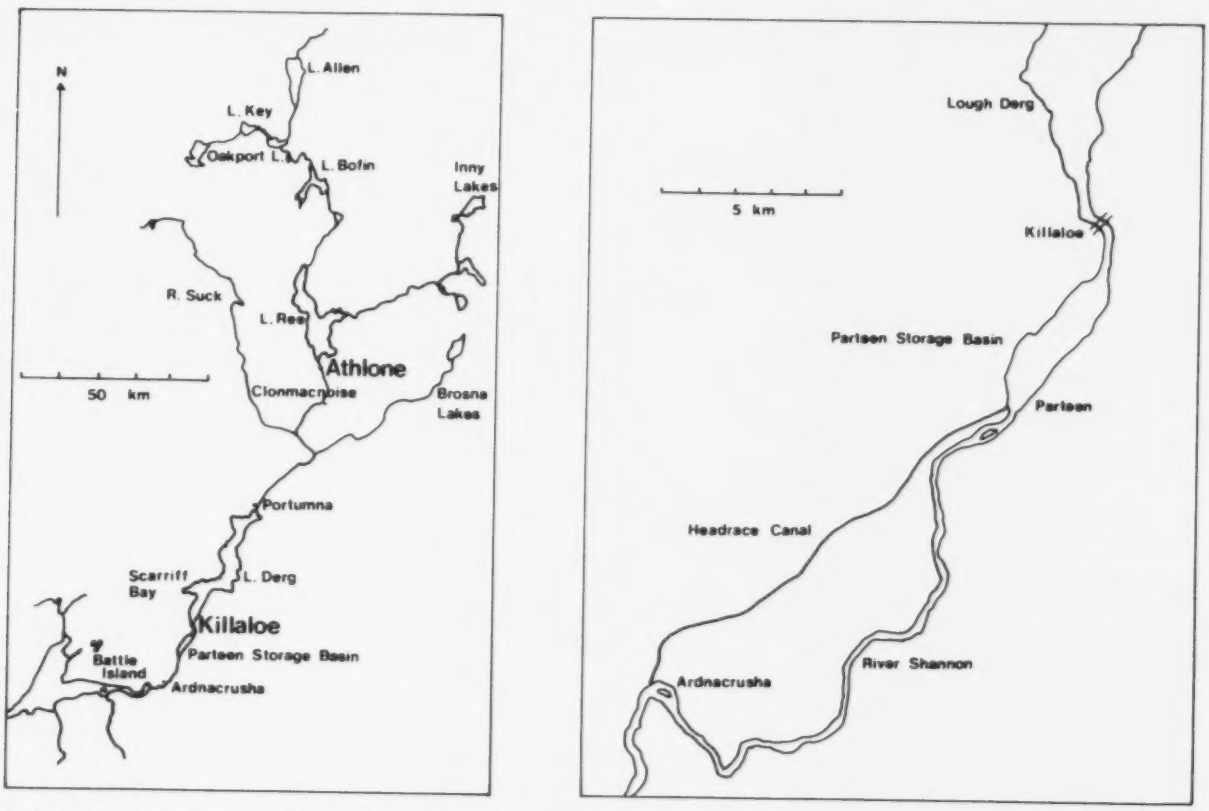

Figure 1. The River Shannon, with major lakes and tributaries.

the first major obstruction to the passage of elvers in a river was erected. This was the hydro-electric dam at Ardnacrusha, in the lower reaches of the River Shannon. This river system occupies one-third of the area of Ireland and had been the principal source of eels (Figure 1).

At the time when the dam was built, it was expected that the elvers would make use of the river bed which bypassed the headrace, and proceed upstream by a salmon ladder. It appeared, however, that elvers were attracted by the stronger current of the tailrace from the generating station and only a small proportion of the stock made use of the bypass. This resulted in a sharp decline in the catch in the early 1950's, the time lag of the order of twenty years resulting from the slow growth rate and late age at maturity of the eels.

The Electricity Supply Board, which owns the entire fishery, began to take active steps to increase the stocks in 1959. Elvers were captured at the tailrace and transported overland for planting in Lough Derg (Figure 1). Planting has taken place annually since and

Table 1. Number of elvers planted (millions).

	Lough Derg	River Suck	Brosna Lakes	Inny Lakes	Lough Ree	Loughs Forbes, Bofin	Lough Key	Lough Allen
1959	7							
1960	1.3							
1961	4							
1962	6							
1963	8.5							
1964	0.9							
1965	1.4							
1966	10.8							
1967	7.3							
1968	8.8		2.7	2.5	2.2			
1969	4.5		2.1		2.1			
1970	2.2			1.2	6.6			
1971	10		0.5	2.2	5	0.7	1.3	0.9
1972	3.7			0.5	2.7			3
1973	8.1			0.4	2.2			
1974	6.2	0.2		1.2	4			
1975				1.1	4		0.3	
1976	2.3	0.4			4.9		0.2	
1977	4.3			0.9	2.9		0.3	
1978	4.5			0.7	6.1	1.6	1.3	
1979	10.3				4.4	1.5	7.5	

elvers for stocking have been sought elsewhere, using two downstream tributaries of the Shannon: the Feale, since 1962, and the Maigue, since 1966. The numbers of elvers transported are shown in Table 1. The great majority of these were glass eels but a proportion of older specimens has always been included.

Extensive long-line fishing took place on the river system until 1968 when fishing for yellow eels was banned so that the immature eels could be preserved. In 1969, a survey of the stocks in Lough Derg was made and, in 1970, Lough Key was studied (Moriarty 1974). On the basis of age determinations, it was concluded that the 1969 survey gave a description of the population before the artificial transport of elvers had taken effect. The same was true of the Lough Key study of 1970.

The stocks of Lough Derg were sampled again in 1974, 1975 and 1979 and sampling will now proceed annually. Figures are provided in Tables 2-4. The catch per unit of effort in water of less than 4 metres was 1.6, in 1969, but had nearly doubled, in 1974, to a figure of 2.9. The following year, the same figure of 2.9 resulted from fishing in the same area. Five years later, the catch had doubled again. The proportion of eels of less than 40 cm rose and the proportion of those of over 50 cm fell in the same period. Again, no significant change took place between 1974 and 1975, but a further increase in the proportion of small eels was apparent in 1979. Fishing in deep water (25 to 30 metres) revealed a spectacular increase in catch per unit effort: from 0.8 in 1969 to 3.3 in 1974 and 4.1 the following year.

Sampling of silver eels at the traps at Killaloe and Athlone began in the winter of 1974. No males were recorded from Athlone in that year, but, at Killaloe, they accounted for 30% of a sample in November. In 1979, in a December sample, they were much more plentiful at 63%. By November, 1979, males made up 33% of the Athlone sample. Thus, there were no males at Athlone six years after the first planting of elvers in lakes upstream of the trap and substantial numbers after eleven years. In 1974, ages of a sample of 87 Killaloe eels were determined and 52% were found to be 19 years and older.

Table 2. Catch per unit of effort.

Place	Date	Effort (nets × days)	Catch	Catch per Unit Effort
Lough Derg	1969	77	123	1.6
	1974	32	94	2.9
	1975	32	94	2.9
	1979	38	243	6.4
South Sloblands	1970	48	408	15.6
	1972	54	15	0.3
	1973	96	457	4.7
	1974	24	157	6.4
	1975	32	427	13.3

Table 3. Length distributions[a] of yellow eels as a percentage of N.

	25-34	35-39	40-44	45-49	50-59	60-69	70-91	N
Lough Derg								
1969	1	11	27	27	29	4	1	271
1974	6	23	27	26	14	2	2	240
1975	6	22	29	26	15	1	1	
1979	3	31	33	19	13	1		442
South Sloblands								
1970	6	25	31	23	10	4	1	408
1974	3	36	40	14	5	1	1	157
1975	3	19	35	28	12	2	1	840

[a] length distribution classes are in centimetres, to the nearest whole number downwards.

Table 4. Length distributions[a] of silver eels as a percentage of N.

	30-34	35-39	40-44	45-49	50-59	60-69	70-110	N
Killaloe								
Nov. 1974	11	14	5	1	10	17	42	99
Nov. 1978	5	2	12	22	31	26	2	65
Dec. 1979	9	47	7	2	17	10	6	135
Athlone								
Nov. 1974	0	0	0	2	3	36	60	103
Nov. 1979	3	18	12	2	18	34	13	77

[a] length distribution classes are in centimetres, to the nearest whole number downwards.

SOUTH SLOBLANDS CHANNEL

The South Sloblands Channel is a much smaller body of water, 100 hectares with a depth of between 0.5 and 3 metres. It contains drainage water from an area of reclaimed land and has a salinity of the order of 2% resulting from seepage of sea water. There is no upstream outlet for eels and this may explain the fact that the density of population was the highest recorded in Ireland. In 1970, the catch per unit effort in the fyke nets was 15.6. The Channel is very rich in nutrients and reaches a high summer temperature. Eels grow relatively fast and a high proportion of otoliths can be read with confidence.

Eels of large sizes (>60 cm) and old ages were scarce and, since there can be no upstream migration, it appears that maturity is reached at relatively young ages and small sizes. Since capture of the silver eels had not been satisfactory, the owners of the fishery were advised to fish f yellow eels with fyke nets. On the basis of the 1970 sample, it was suggested that one season's netting would virtually exhaust the stocks and fishing should be suspended until annual sampling indicated recovery to the 1970 level. It was estimated that this would take five years.

Accordingly, the channel was fished commercially in 1971 and 1972, the catch per unit effort in experimental fishing was 0.3. In the succeeding years, the anticipated increase took place until, in 1975, a catch of 13.3 eels per net indicated that recovery was almost complete (Tables 2 and 3). The owners were advised to fish again in 1976.

DISCUSSION

The fishery at the South Sloblands Channel is small and of limited interest in being based on an unusual habitat. Nevertheless, the study to date has been of value in providing the first figures for Ireland on the actual rate of recovery of an overfished eel stock. The estimate of a five-year recovery period appears to have been correct. In the case of a fishery of this size, it seems that the most economical system of management would be to fish intensively at intervals of five years rather than involve considerably more time and effort in aiming for a sustained annual yield by rejecting small specimens.

The decline in the Shannon silver eel fishery, dating from approximately twenty years after the inhibition of elver ascent, agrees with the observation in 1974 that more than half of a sample of silver eels were aged over 19 years. The second sampling of yellow eels showed a substantial increase in the population, as expected, sixteen years after stocking with elvers had commenced. The third sampling suggested that a levelling of the population density was beginning, but samples taken in 1979, after a four-year gap in the program, showed a further increase.

The principal conclusion from these preliminary studies is that the growth rate of eels is very slow in Irish conditions, as it is in other north temperate populations (Deelder 1970). This means that management plans must be drawn up and put into practice many years before results, in the form of increased yields, can be expected. In these circumstances, the need for monitoring of developments throughout any such scheme is highly desirable to ensure that other development schemes may be effectively planned from the outset.

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DISCUSSION

1. In reply to the question of why growth of eels in the Shannon is poor - worse than in Finland where winters are much colder - it was suggested that it may be related to the fact that Finnish lakes get warmer in summer. Diet may also have an influence.

2. In a situation where there was a good catch of eels in year one and none for the next ten years, it was suggested that eels went overland to avoid the traps.

3. A means of increasing a river system's production by stocking underutilized upstream lake rearing areas was discussed.

4. Questioned on the preying of eels on young salmonids in these rivers/lake systems, Dr. Moriarty indicated that in all his examinations of stomachs, he had very rarely found salmonids. Common food items are found to be cyprinids and cyprinid eggs.

5. The question of competition was raised. Dr. Moriarty indicated that their findings suggest that there is little or no competition between eels and salmonids. There may be competition with cyprinids, but in this case it does not worry them.

6. A discussion took place on the varying migration rates of eels. For example, Dr. Moriarty said on one system it took 5 to 10 years for young eels to move 150 kilometres upstream. He suggested that in some situations eels appear to remain in an area if they have, what seems to be, comfortable accommodation.

THE EUROPEAN EEL SITUATION - DISCUSSION

1. Regarding the return of eels to the "home stream", it was suggested that return is a random process as there is no evidence the progeny return to the stream of origin of their parents.

2. In reply to a question on the possibility of using baited pots to capture yellow eels, Dr. Deelder explained that these could only be successful if fresh bait was used and as they have no good supplies of fresh bait in Holland, they have not been effective. Dutch fishermen have had good success with unbaited pots.

3. The European speakers agreed that silver eels should be totally harvested, but added that it is not possible to do so.

4. Regarding the question of yellow eel density in inland waters, Dr. Moriarty indicated that access of the area to elvers, distance from the sea, availability of food, etc. are some of the principal governing factors.

5. In reply to a question on the relationship of water quality to eel stock density, Dr. Deelder indicated that the quantity of food determines the quantity of eels. At present, there is relatively little known about the effect of water quality on the density of eels - available food appears to be the important factor.

6. Regarding the effect of high river pollution levels on eels, Dr. Deelder referred to the Rhine which is known to have high pollution levels from Switzerland down to the lower reaches. Nevertheless, sampling studies in the lower Rhine have shown that there are large numbers of elvers present.

7. In reply to a question on the suitable quality of eels, Dr. Deelder explained that knowing the proper eels to smoke comes mainly from experience. By tests, good "smokers" should have 22 - 25% fat.

8. In reply to a question of sex determination, Dr. Moriarty explained that at about 35 centimetres, the female gonads have what is described as a "frill", while the male gonads develop slower (are smaller) and appear as a string of sausages.

9. No attempt has been made to improve yellow eel habitat in Europe.

10. Differentiating between yellow and silver eels was discussed for tagging purposes. Dr. Moriarty explained that he could tell the difference between yellow eels and silver eels from their outward appearance. Body firmness of silver eels is a good indicator but eye diameter is a less sure characteristic.

11. There was considerable discussion on the pros and cons of different age determination techniques. It was apparent that this is another area where more information is required.

NORTH AMERICAN EEL RESEARCH AND INVESTIGATIVE REPORTS

LOCAL MOVEMENTS AND HOME-RANGE SIZE OF RADIO-EQUIPPED AMERICAN EELS *(Anguilla rostrata)* FROM LAKE CHAMPLAIN, WITH NOTES ON POPULATION ESTIMATION

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Twenty-three (23) American eels *(Anguilla rostrata)* from Lake Champlain were equipped with internally implanted radio-frequency transmitters and released into the lake in 1979 and 1980. Their positions were noted, periodically, in order to determine the extent of local movement and home range size. Tracks of seven of the 23 eels could not be used for various reasons. Of the remaining sixteen, there was a great deal of variation in rate of movement and home range size. Mean distance moved was 2.4 km (S.D. = 1.5 km) during a mean of 27.6 days (S.D. = 18.5) in a mean area of 29.3 ha (S.D. = 20.6 ha) with a mean daily movement rate of 133.0 m (S.D. = 119.4 m). Some fish remained near the release site for up to two months, while others apparently moved into deep water and were lost to the investigators. Fish released in sites other than the capture site did not appear to home, but all releases were within 2 km of the capture site. Only two fish returned to and remained at the capture site after extensive movement away. Both had been released at the capture site. Four fish passed close to the capture site but did not remain there.

A total of 373 eels were captured, tagged, and released on 19 sampling nights in 1980 to estimate in-shore population size by mark and recapture. Only 32 of these eels were recaptured in 1980. The Floy anchor tag was missing from 6 of the 32 eels, but a wound or scar was noted where the tag had been. Estimated numbers per kilometre of shoreline varied from 116 to 318, with a mean of 215. Estimated number per hectare averaged 429 (S.D. = 202), and estimated mean biomass for areas less than 3.6 m deep was 261 kg/ha, ranging from 161 to 421 kg/ha. This compares to a high of 79 kg/ha in other estimates of biomass for the American eel.

One tagged eel was recaptured at Quebec City, having travelled about 400 km in less than 60 days.

LABAR - DISCUSSION

1. In reply to various questions on tagging in his experimental program, Dr. LaBar explained why he had proceeded with his technique. External transmitters were tried, but in all cases, were torn off by the eel. Ingestible tags have been tried, but lost through regurgitation. Sonic tags were not tried, mainly due to the lack of all the proper equipment.

2. Regarding the question of stress, Dr. LaBar indicated that there was stress, but it had not been measured. He agreed that it should be measured.

FOOD HABITS, AGE AND GROWTH, AND SEX RATIO OF AMERICAN EELS *(Anguilla rostrata)* IN VERMONT WATERS OF LAKE CHAMPLAIN[1]

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EXPANDED ABSTRACT[3]

Lake Champlain is currently being considered as a potential site for small scale commercial fishing for American eels *(Anguilla rostrata)*. To better understand the ecological role of eels in the lake, a study was initiated to determine their food habits, size and age frequencies, and sex ratio.

Eels were captured primarily by electrofishing and baited commercial pots. Electrofishing was restricted to shoreline areas up to 2 m in depth and was generally done after dark, as this is when the eels were feeding most actively. Most eel pots were checked 24-48 hours after being set.

Total length of each specimen was measured to the nearest centimetre and mass was recorded to the nearest gram. Otoliths were ground on 600 grit carbimet paper strips and annual rings counted while observed under a dissecting microscope. Stomach contents were identified, to the lowest possible taxon, enumerated, and measured volumetrically.

The length of 426 eels ranged from 43 cm to 90 cm, with a mean of 67 cm. Weight of 427 eels was between 120 g and 1665 g, with a mean of 638 g. Mean age of 416 eels was 15.9 years, with a range from 8 to 23 years. Length frequency, histograms showed a scarcity of eels under 50 cm and 13 years and a total absence of eels under 40 cm and 8 years. This is believed to be due to eels not arriving in the lake until they have reached about 40 cm. After 80 cm and 17 years, there is a marked drop in the frequency of eels caught. This is believed to be indicative of the emigration of eels from the lake when they reach about 80 cm.

Insects appeared in 42.7% of the 279 eel atomachs that contained food, but accounted for only 9.6% of the total volume. Fish and crayfish were each present in 26.2% of the stomachs and accounted for 38.3% and 30.3% of the total volume, respectively. Gastropods were present in 20.1% of the stomachs, but accounted for less than 2% of the total volume. The nature of the food items found suggests that eels rely heavily on benthic organisms.

Contingency table analysis showed a trend for smaller eels (43-57 cm) to rely more on insects as their primary food source than did larger eels (over 57 cm). Larger eels (73-87 cm) appeared to utilize more fish in their diet than did eels under 73 cm. Nevertheless, these trends were not shown to be statistically significant.

There was little reason to believe that Lake Champlain eels fed significantly on local sport fish or their eggs. There is reason to suspect, however, that the eels may be competing with sport fish for available food.

Of the eels captured for this study, 356 were sexed using histological methods. All were females.

FACEY - DISCUSSION

1. The question was raised of eels feeding on dead animals. The speaker was aware of these reports, but stated that his studies had not indicated this characteristic.

2. Regarding the question of eels feeding on fish, the authors' studies did not show any preference towards a particular species.

3. It was suggested, from the list of fish species preyed on by eels, that they prefer nocturnally active fish.

4. Studies did not show that eels feed on fish eggs.

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[3]For more detail, please refer to:
Facey, D. E., and G. W. LaBar. 1981. Biology of American Eels in Lake Champlain, Vermont. Trans. Am. Fish. Soc. 110: 396-402.

CHEMICAL ANALYSES OF THE OPTICALLY DIFFERENT ZONES IN EEL OTOLITHS

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ABSTRACT

Electron microprobe X-ray analysis was used to obtain a microtopographic elemental description of the chemical composition and zonation of the otoliths of European eels, *Anguilla anguilla*, from the Shannon River, in County Tipperary, Ireland, and American eels, *Anguilla rostrata*, from the St. Lawrence River in Ontario, Canada.

Three types of optically different zonal patterns are apparent in sectioned otoliths of large eels from the upper St. Lawrence River and Lake Ontario. One type is associated with the NUCLEUS and is composed of broad, opaque zones separated by two to four narrow, translucent zones (considered to be year marks or annuli). Outside the nucleus is a set of zones referred to as the zones of TRANSITION. They are associated with migration up the St. Lawrence River, and are composed of narrow, opaque zones separated by two to four broad, diffuse, translucent zones. Outside this region is the zonation associated with the EDGE. It contains numerous uniform, broad, opaque zones separated by up to approximately ten very distinct, narrow, translucent zones. The zones of this region are associated with growth after migration. Optical zonation is enhanced if photographic negative prints are made in transmitted light directly from thin sections used as negatives.

Eel otoliths, like the otoliths of other species, are essentially calcium carbonate, and contain a very small amount of proteinaceous material (<3% by weight). The more translucent otoliths of "silver" American eels are more heavily calcified (38.60 ± 0.112, mean ± 95% CI) than are the more opaque otoliths of pike, *Esox lucius* (36.71 ± 0.811).

Spectrometer scans, using lithium fluoride and ammonium dihydrogen phosphate crystals, indicated that there are both quantitative and qualitative differences in the elemental composition, not only within the otolith when the nucleus and edge are compared, but also between otoliths of the two species of eels. The European and American species appear to originate from different spawning stocks. European eel otoliths contained slightly more calcium than did otoliths of American eels (up to 5 to 7%). Regardless of the species, the edge contained more calcium (up to 3 to 5% by weight) than did the nucleus (up to 15 to 18%).

Strontium concentration was more variable than that of calcium and was twice as high in the otoliths of American eels. Regardless of species, strontium was approximately three times more concentrated in the nucleus than at the edge of the otolith.

Increase in calcium concentration with age appears to be inversely related to growth rate in eels, as in other species. Translucent zones in eel otoliths were more heavily calcified than were adjacent opaque zones (up to 1% calcium by weight).

Electron microprobe X-ray analysis of the surface of sections that appeared to be uniformly translucent indicated that calcium zonation exists even though optical zonation is not apparent. Hence, microprobe analysis could be used to detect zonation to mechanize and automate the age assessment of eels.

INTRODUCTION

Otoliths of both the European eel, *Anguilla anguilla*, and the American eel, *Anguilla rostrata*, have frequently been used for age and growth assessment. Tests of the validity of age assessment using otoliths from eels of known age that were reared in ponds gave very poor results, regardless of the methods used for preparation and interpretation (Deelder 1981). Results from that study, as well as those conducted on otoliths from eels of unknown age (Hurley 1972), indicate that it is extremely difficult to interpret age from optical zonation of eel otoliths, and the results should be treated with caution. It is difficult to obtain consistent results when the same otoliths are examined repeatedly. This, in itself, signals that there are problems.

A systematic analysis of the otolith method of assessing age and growth of eels is needed. The purpose of this study was to begin this systematic analysis by examining the chemical composition of eel otoliths. There has been considerable speculation as to the composition of, and the factors causing, the optically different zones in fish otoliths. Their composition needs to be described more adequately. The chemical characteristics associated with optical zonation in other species and other calcified structures have been analysed (Casselman 1978). The current study was conducted to determine if the translucent zones in the otoliths of this species were similarly hypermineralized. Otoliths from both European and American eels were studied to see if the results were similar and could be applied more generally.

Electron microprobe X-ray analysis was used to elucidate the elemental composition of these otoliths by both point and line scan analyses. Electron microprobe X-ray analysis permits the direct analysis of the chemical composition of fish calcified tissue (Casselman 1978). The analytical capabilities of the electron microprobe

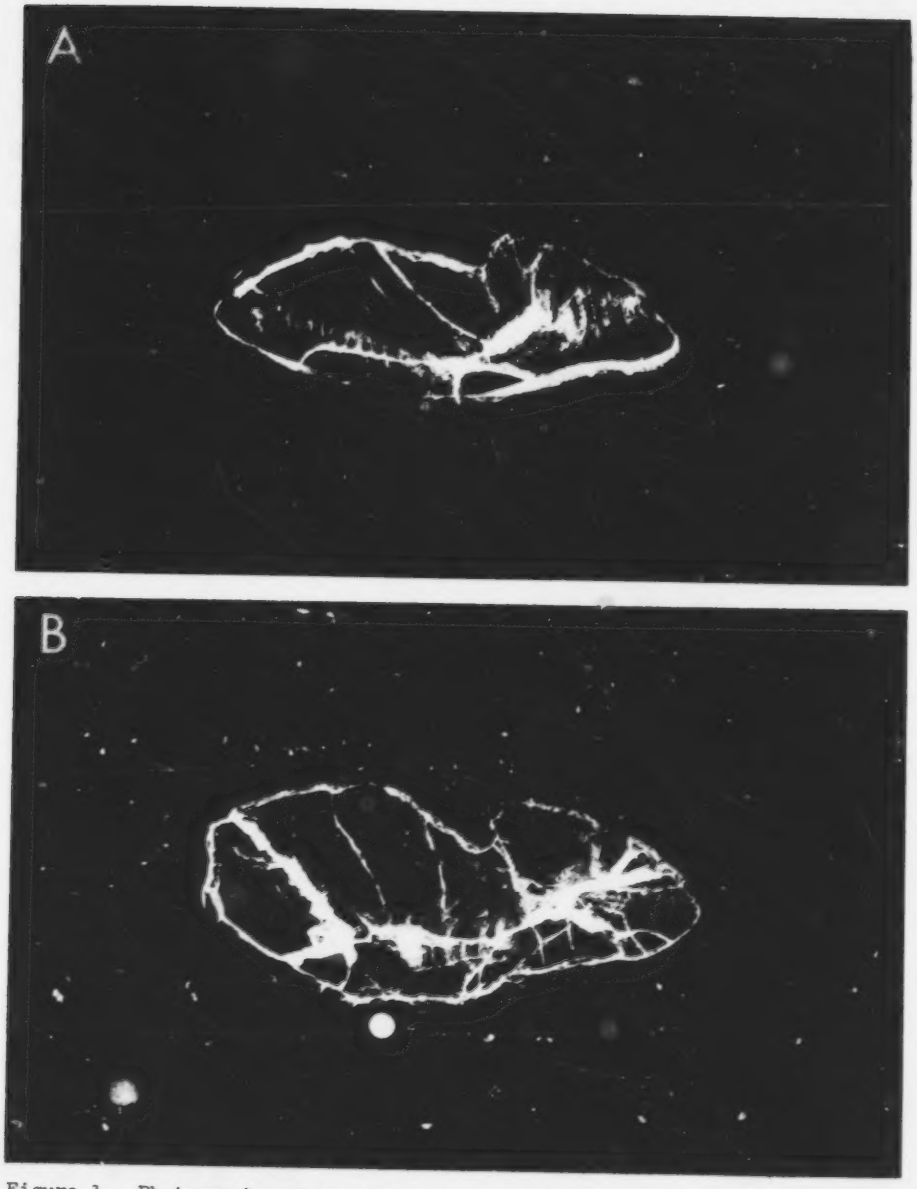

Figure 1. Photographs of the thin cross-sections from the middle of the otoliths of two species of eels. Photographs made with a Recordak Magnaprint Reader Model PE-1A by Eastman Kodak Co., Rochester, N.Y. The translucent zones associated with annuli are marked with dark circles. In transmitted light (photographic negative), thickness 200 µm (x00). A--European eel, *Anguilla anguilla*, T.L. 712 mm, 746 g. female. Captured January 7, 1974, Shannon River, County Tipperary, Ireland. Age 18. B--American eel, *Anguilla rostrata*, T. L. 720 mm, 725 g, female. Captured March 16, 1974, St. Lawrence River, Ontario. Age 15.

provide a unique opportunity to examine the microtopographic elemental description of the qualitative and quantitative nature of the calcified tissue. This technique permits an examination of the elemental composition of minute volumes (several cubic microns, depending upon the density) of intact tissue.

MATERIALS AND METHODS

Otoliths from twelve individuals of each of the two species were examined and analysed. The otoliths were obtained from large eels (fe-

male) collected during the winter of 1974 from the Shannon River in County Tipperary, Ireland, and from large "silver" (light coloured) eels collected from the St. Lawrence River during the same year. Eels of this colour are considered to be maturing and of the size that would be migrating to the sea.

The otoliths were removed, dried, and subsequently embedded, then cross-sectioned through the middle and prepared for electron microprobe X-ray analysis using a method outlined by Casselman (1978). Thin sections were cut that ranged in thickness from 100 to 400μ; however, most sections were approximately 200μ. Typical examples of thin sections used in these analyses are presented in Figure 1. These photographic prints were made directly from thin sections of the otoliths on a Magnaprint reader (model PE-1A by Eastman-Kodak Company, Rochester, N.Y.). Optical zonation was apparent on these prints. The assessed age for the American eel in Fig. 1-B is typical of the oldest individuals seen in the population. This otolith was interpreted to be from a fish that spent three years in the marine environment, two years in migration up the St. Lawrence River, and ten years post-migration in the upper St. Lawrence-Lake Ontario environment. Very few eels are observed that spend more than ten years in the upper St.

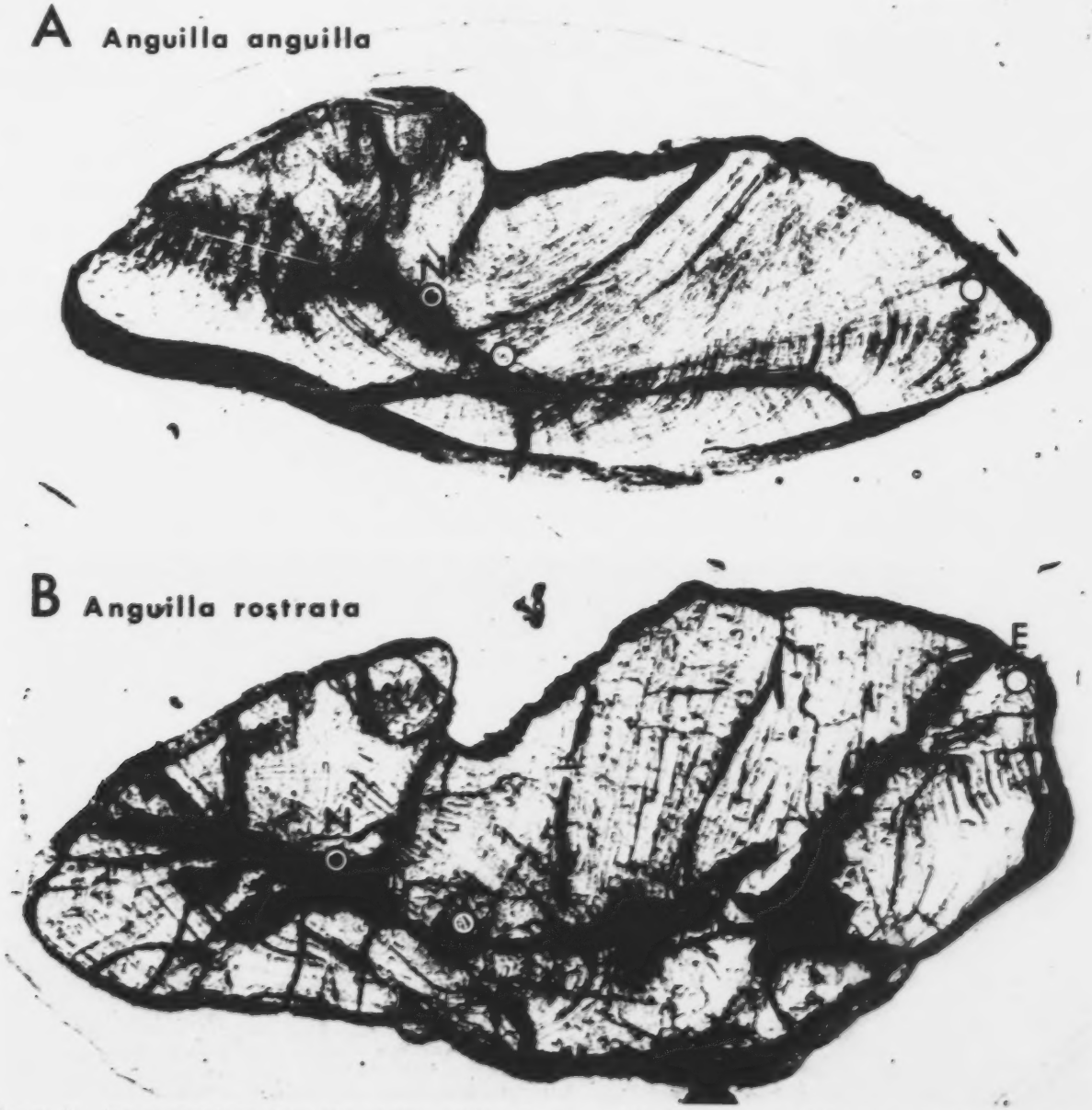

Figure 2 - Cross-sections from the middle of the European (A) and American (B) eel otoliths illustrated in Fig. 1. Circles and letters indicate areas analysed with the electron microprobe--N-nucleus, E-edge, and T-translucent zones between the nucleus and edge. In transmitted light (photographic positive), thickness 200 μm (x00).

Lawrence River and Lake Ontario (Casselman, unpublished data).

To examine for differences within and between otoliths, specific locations were analysed by point analysis. Specific locations used in point analysis of the otoliths are illustrated in Fig. 2 for the two otoliths presented in Fig. 1. These locations are: in the NUCLEUS (N), at the EDGE (E), and in a part of the otolith containing broad, translucent zones, referred to as the region of TRANSITION (T), associated with migration.

To examine the elemental composition of the otoliths, spectrometer scans were conducted with three types of crystals: lithium fluoride (LIF), ammonium dihydrogen phosphate (ADP) and rubidium acid phthalate (RAP).

The specific operating conditions used in these electron microprobe X-ray analyses are described by Casselman (1978), and use an electron acceleration voltage of 15 kV and a specimen current of 0.01 μA.

RESULTS AND DISCUSSION

OPTICAL ZONATION

The degree of translucency of a calcified structure is inversely related to the thickness of the section. Nevertheless, in general, optical zonation of cross-sections of eel otoliths was indistinct, and the otoliths were quite translucent. Photographic negative prints made directly from thin sections of these eel otoliths (Fig. 1) appear to enhance optical zonation when compared with photographic positive prints made through photographic negatives (Fig. 2) As

Table 1. Physical and chemical composition of a typical fish otolith. Data from Casselman (1978). Whole otoliths were analysed, except for electron microprobe X-ray analysis in which otolith slices were used along with point analysis. Analyses reported as precent dry weight.

	N	Range	Mean	95% CI
Moisture content				
Wet tissue air dried (22C)	6	1.5-4.2	2.5	0.97
Air dried tissue (22C) oven dried to 100C	6	0.4-0.6	0.5	0.11
Specific gravity[a]	25	2.672-2.722	2.707	0.0054
Ash residue[b]	14	55.09-56.02	55.28	1.404
Calcium[c]	13	35.11-38.63	36.71	0.811
Phosphorus[c]	13	0.04-0.10	0.06	0.013
Nitrogen[d]	7	0.33-0.54	0.44	0.076
Protein			2.8	

[a]Determined by using an isodensimetric technique.

[b]Determined at 640°C.

[c]Determined by electron microprobe analysis.

[d]Determined by micro-Kjeldahl technique.

with other calcified structures, thinner sections of these otoliths produced broad, translucent zones and narrow, opaque zones. Thicker sections, however, produced narrow, translucent zones and broader, opaque zones. Too few otoliths of the European eels were examined to notice any specific regularity in pattern in the otolith. Distinct types of regional zonation are apparent, however, in otoliths of the American eels. Three types of zonal patterns exist in otoliths of large eels from the upper St. Lawrence River and Lake Ontario. One type of zonation is associated with the NUCLEUS. In this region, there are several broad, opaque zones separated by narrow, translucent zones. These translucent zones are relatively distinct and are similar in appearance. There are usually two to four of these translucent zones associated with the NUCLEUS. For the purpose of age assessment, it is assumed that each of these translucent zones is associated with a year mark or an "annulus". Outside the nucleus is a set of zones referred to as the zones of TRANSITION. Recent analyses indicate that these zones are associated with migration up the St. Lawrence River (Casselman, unpublished data). The opaque zones in this region are narrow and are separated by broad, diffuse, translucent zones which, under higher magnification, appear to be composed of several translucent zones. This region of the otolith usually contains two to three broad, translucent zones. Outside this region is a region referred to as the EDGE. In thicker sections, the EDGE contains numerous uniformly broad, opaque zones separated by very distinct, narrow, translucent zones. The first opaque zone outside the region of transition usually is narrower than are subsequent opaque zones. These zones are associated with life after migration, either in the upper St. Lawrence River or Lake Ontario.

Eel otoliths are relatively translucent when compared with the otoliths of other species, hence would be expected to have a greater mineral content, since it has been shown that the mineral content is directly related to translucency (Casselman 1978). The translucency of eel otoliths is more obvious when illustrated in transmitted light and presented as a photographic positive (Fig. 2).

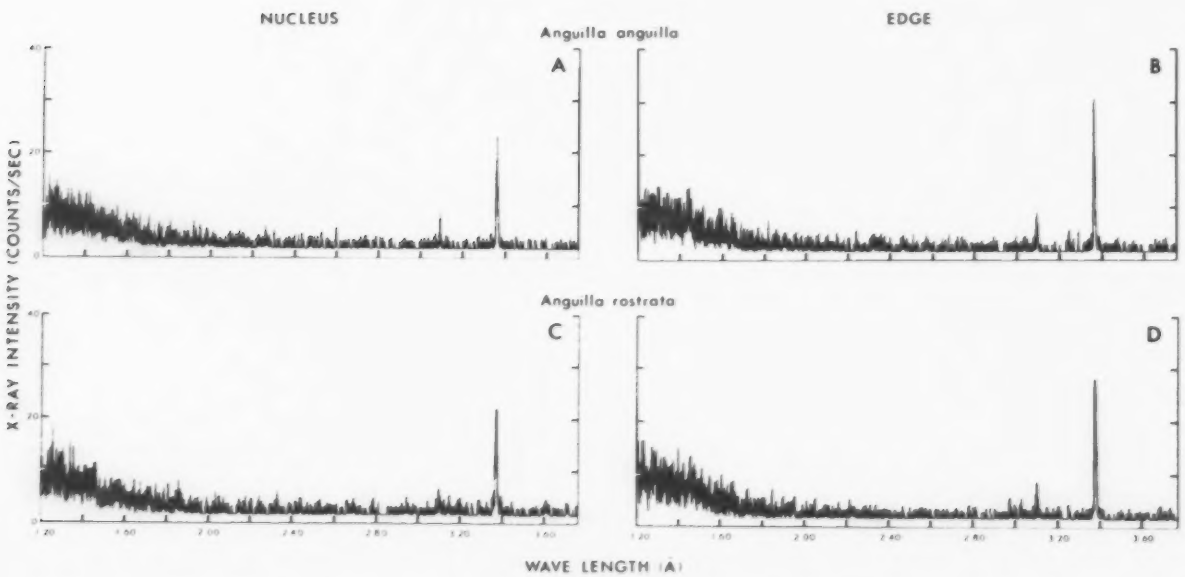

Figure 3. Wavelength profiles from recorder tracings of spectrometer scans with a lithium fluoride (LIF) crystal. Typical relations between X-ray intensity (counts/sec) and wavelength (Å) for the nucleus (A and C) and edge (B and D) of otolith slices of European (A and B) and American (C and D) eels. Operating conditions: electron acceleration voltage 15 kV and specimen current 0.01 μA.

CHEMICAL COMPOSITION

Fish otoliths are composed of calcium carbonate in an organic matrix. Calcium carbonate is probably in the form of aragonite (Degens et al, 1969). Compositional analyses of a number of otoliths from several species indicate that the organic phase, which is proteinaceous, comprises less than 3% of the weight of the otolith (Table 1). Fish otoliths are very compact, calcareous accretions that have a relatively high specific gravity and contain a relatively small amount of moisture when compared with other calcified structures (Casselman 1978). Calcium is the major element in the otoliths (northern pike, *Esox lucius*--Ca = 36.71% ± 0.811 [mean ± 95% confidence interval]), but other minor elements such as nitrogen and phosphorus are present (Table 1). Ash residue, as determined at 640°C, is approximately equal to the oxide weight, and is equal to approximately 50% of the fresh weight of the otolith (Table 1).

The elemental composition of eel otoliths is generally similar to that of the otoliths of other species. Regardless of species or the region analysed, the X-ray peaks were, in general, similar. Spectrometer scans, using a lithium fluoride crystal, showed two major peaks, both associated with calcium--CaK_β at a wavelength of approximately 3.09 Å, and CaK_α at approximately 3.36 Å (e.g. Fig. 3, analyses of otoliths illustrated in Fig. 2). Although other peaks were detected and were subsequently shown to be above background, they were not within the limits of detection using the present operating conditions.

Spectrometer scans, using an ammonium dihydrogen phosphate crystal, showed similar results but more numerous peaks associated with calcium--CaK_β at a wavelength of approximately 3.09 Å, CaK_α at approximately 3.37 Å, CaK_β^2 at 6.61, CaK_α^2 at 6.72 Å, and CaK_β^2 at 9.27 Å (e.g. Fig. 4, analyses of otolith illustrated in Fig.

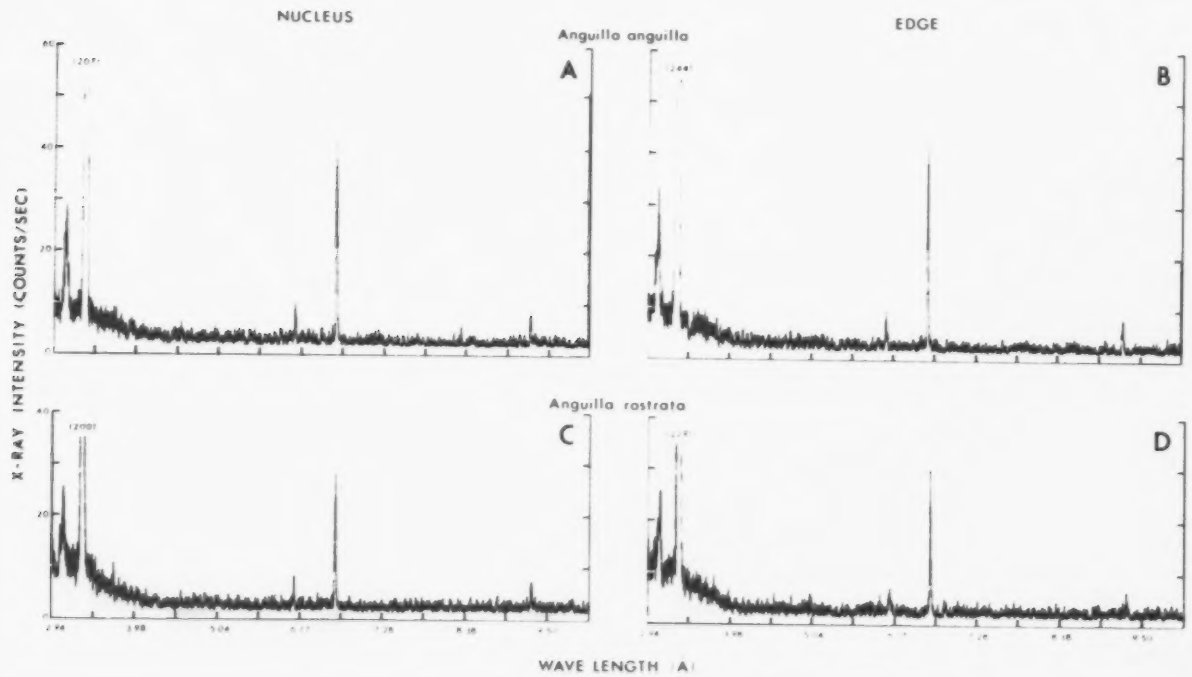

Figure 4. Wavelength profiles from recorder tracings of spectrometer scans with an ammonium dihydrogen phosphate (ADP) crystal. Typical relations between X-ray intensity (counts/sec) and wavelength(Å) for the nucleus (A and C) and edge (B and D) of otolith slices of European (A and B) and American (C and D) eels. Operating conditions--electron acceleration voltage 15 kV, and specimen current 0.01 μA.

2). It was apparent that calcium was the major element in these otoliths but, as with the lithium fluoride crystal, some minor peaks were recognized and occurred consistently in these spectrometer scans. These two types of scans measured the relative concentration of elements heavier than magnesium. Preliminary analyses were conducted with a rubidium acid phthalate (RAP) crystal, but the only major peaks were third and fourth order CaK_{α} and CaK_{β}. Machine problems developed that could not be overcome, so only preliminary analyses were conducted with this crystal.

The spectrometer scans presented in Figs. 3 and 4 are typical of those obtained when two areas of the otoliths of the two species were compared. Pulse height analysis conducted on these X-ray intensities indicated that there were recognizable differences in the X-ray scans for both crystals when the nuclei of the two species were compared. This result is best illustrated by intensity of the X-ray emission in the nucleus at approximately 8.38 Å. A peak appeared in the scan of the nucleus of the European eel otolith, but not in that of the American eel otolith. This peak could not be specifically identified; however, AlK_{α} is known to have a wavelength of 8.33 Å. These differences indicate that the elemental composition of the otoliths of these two species, especially of the nucleus, is different. The elemental composition of either the food or environmental water, or both, of the European and American species of eels during their early years of life (leptocephali) is different, hence they appear to be from stocks of different origins (spawning locations).

Although the X-ray intensities illustrated in Figs. 3 and 4 are not strictly quantitative, they provide some indication as to differences in the calcium contents between species and regions within the otolith. For these specific scans, the otoliths of the European eel contained approximately 5 to 7% more calcium than did otoliths of the American eel. Regardless of species, the edge contained from 15 to 18% more calcium than did the nucleus. This type of analysis involves longer exposure to electron bombardment, hence the results represent an extreme difference. Quantitative analysis, using calibrated standards and conducted on a different set of five otoliths, substantiated that these

Table 2. Calcium and strontium content (% dry weight) of five European and five American eel otoliths analysed by electron microprobe X-ray analysis at three points at two locations in the otoliths (nucleus and edge). The combined results are also provided.

	Anguilla anguilla			*Anguilla rostrata*			Combined		
	Nucleus	Edge	Combined	Nucleus	Edge	Combined	Nucleus	Edge	Combined
Calcium									
N	15	15	30	15	15	30	30	30	60
Range	37.79-40.58	37.79-42.88	37.79-42.88	37.29-40.58	37.77-40.95	37.29-40.95	37.29-40.58	37.77-42.88	37.29-42.88
$\bar{x}$	38.48	38.83	38.65	38.11	38.98	38.55	38.30	38.90	38.60
SE	0.129	0.198		0.216	0.235				
Strontium									
N	15	15	30	15	15	30	30	30	60
Range	0.00-0.27	0.00-0.19	0.00-0.27	0.00-0.64	0.00-0.16	0.00-0.64	0.00-0.64	0.00-0.19	0.00-0.64
$\bar{x}$	0.12	0.04	0.08	0.22	0.07	0.15	0.17	0.05	0.11
SE	0.053	0.038		0.142	0.021				
Sr/Ca	0.0032	0.0010		0.0059	0.0019		0.0044	0.0014	
Sr/Ca in nucleus / Sr/Ca in edge		3.20			3.10			3.14	

calcium differences occurred but were not as large (Table 2); however, absolute differences of up to 3% calcium by weight were measured between the nucleus and the edge.

The relatively more translucent eel otoliths contained significantly more calcium (38.60 ± 0.112) (Table 2) than did the less translucent otoliths of pike (Table 1).

When very long counting times (10 sec) were used, strontium was found to be present and within the limits of detection. On the average, the otoliths contained 0.11% strontium by weight. This strontium concentration was higher than the identical values obtained for scales of brown trout, *Salmo trutta* (Bagenal et al. 1973) and pike cleithra (Casselman 1978) (0.03 ± 0.007% by weight), but lower than the values reported for bone and scale of *Latimeria* (0.17-0.20% by weight)(Cowgill et al. 1968). The strontium concentration was found to be much more variable than that of calcium (Table 2), but showed a marked difference between species. Otoliths from American eel contained approximately twice as much strontium as did the otoliths of European eel. Regional differences within the same otolith were detected. Generally, there was approximately three times as much strontium in the nucleus as at the edge of the otolith (Table 2). Similar results have been reported for scales of anadromous fish (Bagenal et al. 1973). Strontium content of sea water is approximately 20 to 40 times greater than that of fresh water (upper St. Lawrence River and Lake Ontario, 1973, Sr ∿ 0.160 mg/ℓ), and that part of the otolith that corresponded to marine life had a higher strontium content.

The Sr/Ca ratios in the nucleus are very similar to that of coccolith tests and foram shells found in the deep sea (Broecker 1974), and are only about one-third to one-sixth of the Sr/Ca ratio for sea water (Angino et al. 1966). In the nucleus of the otolith, the discrimination against strontium is by a factor of about 4. A similar but slightly lower level of discrimination (3) appears to exist in the portion of the otolith deposited when the eel is in the freshwater environment, since the Sr/Ca ratio of fresh water (St. Lawrence River, 1973, Sr/Ca ratio = (0.160 mg/ℓ)/(40.0 mg/ℓ) = 0.004) is approximately one-quarter that of sea water (Sr/Ca ratio = (7.5 mg/ℓ)/(400 mg/ℓ) = 0.0188 (Angino et al. 1966; Broecker 1974)).

Since the nucleus is known to represent growth in the marine environment and the edge growth in the freshwater environment, then it is apparent that the deposition of calcium is strongly regulated, since the calcium in the marine environment is approximately ten times that in the freshwater environment. Discrimination against calcium in the marine environment appears to be by a factor of at least 10. At these environmental levels calcium concentration in bony structures of fish is strongly regulated, whereas the strontium concentration is more variable. Similar conclusions have been reached by Berg (1972). If anything, the calcium content in the otolith is greater during freshwater growth than during marine growth. Nevertheless, it is known that the calcium content of the calcified structure is inversely related to growth rate (Casselman 1978). The difference in the calcium content within eel otoliths can be explained by the calcium concentration-growth rate relationship, since growth is known to decrease with age, especially the ages associated with these analyses. The rate of appositional growth at the edge (freshwater) is less than that in the nucleus (marine).

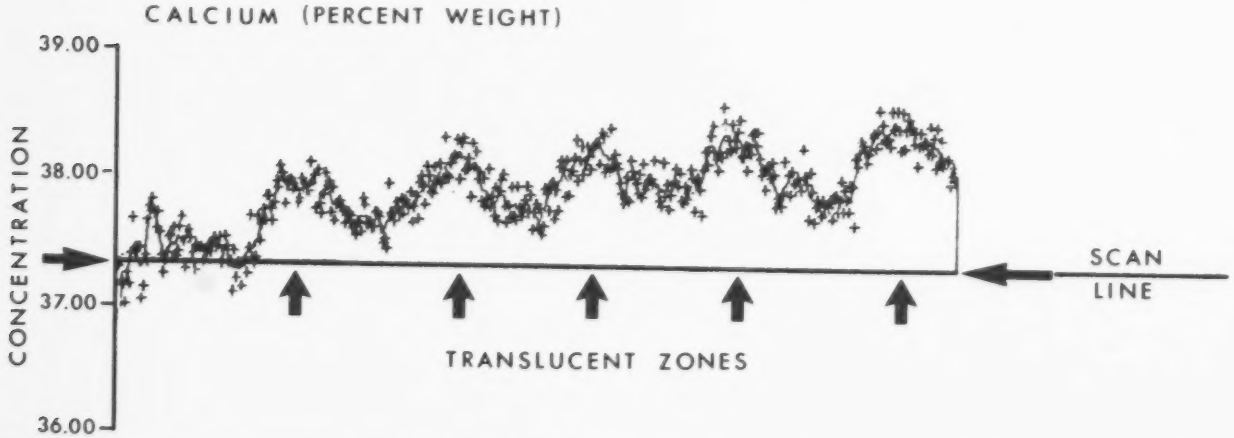

Figure 5. Microprobe analysis for calcium concentrations (percent dry weight) across five opaque and five adjacent translucent zones in a European eel otolith. Line scan analyses were conducted from the nucleus towards the edge of the eel otolith illustrated in Fig. 2-A. Arrows mark the beginning (right) and the end (left) of the line scan analysis along the white line between the arrows. Calcium concentration expressed as percent dry weight from left to right. Actual distance 410 µm. Operating conditions: electron acceleration voltage 15 kV and specimen current 0.01 µA.

In the translucent zones associated with the region of transition, the calcium content was approximately the same as that on the edge. These zones appear to be deposited during migration when linear growth rate of the otolith is slow. The calcium and strontium content in these zones is more similar to that found on the edge of the otolith.

Calcium content is inversely related to growth rate and directly related to translucency in eel otoliths, as in the otoliths of other species (Casselman 1978). To examine the elemental composition within and between zones, line scan analyses were conducted across the optically different zones in the otolith. The translucent zones were more heavily calcified than were the adjacent opaque zones (e.g. Fig. 5). The absolute difference between adjacent zones, in some cases, reached 1%. When thin sections, up to a thickness of approximately 200 μ, were examined in transmitted light, optical zonation, especially near the edge, was not apparent. In some cases, even thicker sections, from 300 to 400 μ, showed no apparent zonation. Electron microprobe analysis of the surface of sections that appeared to be uniformly translucent indicated that calcium zonation existed even though optical zonation was not apparent. Hence, microprobe analysis could be used to assess the age of fish by using chemical rather than optical zonation. This type of chemical zonation has been observed in pike cleithra (Casselman 1974) and in centra of spiny dogfish, *Squalus acanthias* (Jones and Geen 1977). Chemical zonation is not as great in otoliths as in other calcified structures of fish (Casselman 1974, 1978), but this is probably related to the fact that their organic content is low, and is probably less variable between zones. Chemical zonation could, however, be used to mechanize and automate the age interpretation of eel otoliths.

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A RE-EXAMINATION OF STATISTICS PERTAINING TO GROWTH, YIELD AND ESCAPEMENT IN THE AMERICAN EEL (*Anguilla rostrata*) STOCKS OF LAKE ONTARIO

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INTRODUCTION

Results of tagging studies, length-weight statistics and age determinations provided parameters to employ in a model simulation to predict yield and adult escapement under various levels of natural and fishing mortalities. Using cohort analysis, it was discovered that maximum yield per recruit maximizes at between 20 and 40% exploitation, that adult emigration can be greatly reduced at these same exploitation levels, and that wastage of effort occurs at high exploitation mainly because only smaller eels are harvested.

The position of the American eel (*Anguilla rostrata*) in Canadian waters of eastern Lake Ontario has progressed from one of little economic importance, and in fact a considerable nuisance, in the 1950s to one of primary importance to the commercial fishery in the 1970s. Eels have been the subject of continuing study at the Glenora Fisheries Station since 1959 and reports on both the biology and commercial fishery for this species are extant (Hurley 1972, 1973).

The data that formed the basis of those reports were re-examined in order to derive a yield model that would simulate various levels of natural mortality, fishing mortality or exploitation and adult emigration from Lake Ontario. This paper sets out our thinking and the main conclusions derived from the model simulations; but, this is not a complete exposition of the yield model, which can be found in Christie et al (in preparation).

METHODS

Eels were captured in hoopnets, set in Prince Edward Bay on the south shore of Prince Edward County, in early summer of the years 1959 to 1964 and tagged with a split ring tag inserted through the lower jaw and welded shut (Vladykov 1957). Eels were released either at the tagging site or within a few kilometres of it.

Tagged eels were recaptured, by commercial fishermen, in hoopnets or setlines in the spring and summer months in eastern Lake Ontario and also in the weir fishery, between mid September and late October, in the St. Lawrence River near Quebec City.

Data on length, weight, body colouration, pectoral fin length, interorbital distance and eye diameter were collected at the time of tagging. Measurements of length and weight of recaptured eels were usually returned, along with the tag, to obtain the posted reward.

Other eels were sacrificed to obtain the otoliths, which were sectioned, polished, and immersed in glycerine, for age determinations. Interpretation of eel otoliths requires considerable practice and patience, but our age determinations agreed well with known growth increments obtained from tag returns. Thus, we were reasonably confident in our data.

OBSERVATIONS AND DISCUSSION

ESCAPEMENT:

The eel size frequency distributions from samples taken from the eastern Lake Ontario commercial catch (Hurley 1973) showed that eels first became vulnerable at about 400 mm and the numbers increased by size class to a peak lying somewhere between 600 and 900 mm (depending on fishing pressure and recruitment). The frequency of occurrence of larger animals lying outside this range declined precipitously, and it was taken that this reflected the loss of eels to emigration.

Seaward migration of eels appeared to be size-related. This was more forcibly indicated when the proportion of recaptured emigrating eels in the first year following tagging to the numbers of recaptured emigrants in all subsequent years was plotted as a function of body length (Fig. 1). The solid line in Figure 1 was derived from catch length frequencies obtained from the commercial fishery.

The difference between these lines probably reflects the fact that tagging occurred in early spring, yet recapture did not occur until late summer when nearly a full seasons' growth had

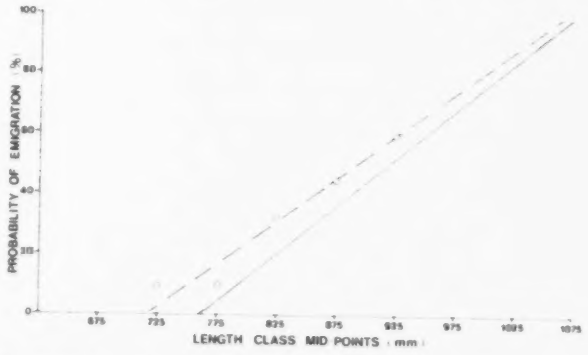

Figure 1. Percent probability of eel emigration based on size class. Open circles and dashed line derived from tag returns from emigrants as a ratio of first year recaptures to total emigrant recaptures in all years. Solid line derived from catch length frequencies (Hurley 1972, Fig. 2).

been added. This would result in smaller sized eels being reported as emigrants and thus, shift the dashed line to the left.

GROWTH:

Eels between 480 and 800 mm in length showed allometric growth ($\log_{10}W = 3.77 \log_{10}L - 7.88$) but symmetric growth between 830 and 1080 mm ($\log_{10}W = 2.98 \log_{10}L - 5.59$). This shift in the length weight relationship appears to be related to physiological preparation for emigration and is similar to that found by Frost (1945) among European eels (*Anguilla anguilla*).

We believed initially that perhaps the larger, fatter eels emigrated and by removal of these eels from the population our sampling of large individuals in Lake Ontario would be biased to less fat individuals. This did not, however, prove to be correct since recaptured St. Lawrence River migrants were not significantly different ($\log_{10}W = 2.94 \log_{10}L - 5.49$) from their non-migrating counterparts.

FISHING STRATEGY:

For the fishery, there is an obvious advantage in capturing the largest size of eels just prior to their emigration. This results in the greatest weight for length of individuals. Nevertheless, the fact that the probability of emigration rises rapidly beyond 800 mm and the length-weight relationship shows a decrease in weight for length beyond that size would argue that maximum effort be directed at eels just prior to their attaining 800 mm in length.

The fact that the probability of emigration rises beyond 800 mm (Fig. 1), but does not reach virtually 100% until over 1000 mm, means that not all the larger eels emigrate. Early on it was thought relative levels of escapement might be detected by physical changes in the eels associated with the silvering (or bronzing) process. Relative eye size, interorbital distance and pectoral fin length, however, showed no tendency to increase among the largest eels examined. Colouration was highly variable, and the eels were not distinguishable in this respect either, when tagged in the spring prior to their downstream migration.

From these observations, we concluded that impending emigration could not be detected by morphological differences and that the best fishing strategy was to achieve a knife-edge selection at about age 11, when eels averaged about 700 mm in length.

YIELD AND ESCAPEMENT:

Using our estimates of eel growth rate and the rate of escapement derived from the probability of downriver recapture of tagged fish, we conducted a simple modelling study. In each case we began with an input of 1000 recruiting elvers and followed their fate to age 18 under various constant levels of natural mortality and varying exploitation rates. Because of our lack of data on the subject, we postulated three separate exploitation scenarios. In the first, exploitation was set to be zero at age 4 and rose linearly with age to reach its maximum stated level at age 13. In the second, it rose from zero at age 4 to a maximum at age 6. Finally, we posed a knife-edge selection where exploitation rose to its maximum at one age. The age chosen was 11 years, which from samples of the commercial catch was the age where about 50% of catch occurred.

Natural mortality values for eels in Lake Ontario are not known, but because they have no natural enemies, it is assumed that the values are low. Overwintering mortality may be important and we postulated that eel fatness at the onset of winter may be important in their ability to survive until spring. We calculated that mortality would decline exponentially as the eel age-weight increased. We also examined the case where natural mortality was set at a constant annual value.

A further refinement to the model was to postulate that natural mortality, if it occurred primarily during the winter, happened prior to and separate from exploitation and emigration. It was, therefore, noncompetitive. On the other hand, exploitation and emigration occurred in the May-September period and, thus, would be competitive over the range of sizes where emigration became an increasing probability.

Results of the model simulations, although differing in specifics, were consistent in their general features. In the first place, yield per recruit rises to a maximum at relatively modest levels of exploitation. This was true regardless of the manner in which exploitation was allowed to change. Several scenarios are illustrated in which the manner of exploitation was allowed to vary (Fig. 2). When exploitation began at age 5 and rose to its maximum stated level at age 6, yield per recruit was maximum at 20% exploitation rate, but the average size of eels taken was small (380 g) When exploitation occurred more gradually over several years, yield per recruit increased substantially, together with the mean weight of eels taken. In addition, delaying onset fishing to later ages increased the yield per recruit and average weight of eels taken. If fishing could achieve knife-edge selection, for example at age 11, as illustrated in Figure 2, then maximum yield per recruit would continue to increase somewhat over several exploitation rates, but not appreciably so beyond 40% exploitation. In addition, average weight of captured eels was considerably greater (845 g) compared to those cases where exploitation occurred at earlier ages.

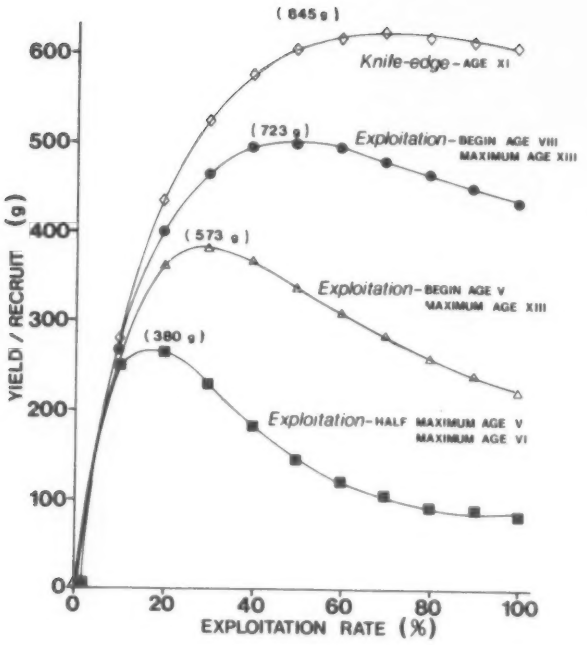

Figure 2. Yield per recruit of eels assuming a level of natural mortality at 10% decreasing logarithmically with four different types of exploitation.

The model also forcefully illustrates the fact that emigration can be reduced to low levels at modest exploitation rates (Table 1). The fishery, however, does not gain in this case because there is a serious reduction in yield. To illustrate this point, notice that in the case where exploitation occurs at age 6, emigrating biomass becomes small at 20% exploitation (Table 1), but yield per recruit also is small (Fig. 2). It is apparent that knife-edge selection, although permitting a greater emigrating biomass (Table 1), produces the maximum yield per recruit (Fig. 2).

It is also important to note that increasing exploitation rates, in any of the scenarios examined, did not result in a great yield, but it did not result in a collapse either. A collapse did not occur because gains were made from the eels that would have emigrated. There is a real potential for wastage of effort and yield per recruit if exploitation levels reach too high a level.

The virtual elimination of adult eel emigration from Lake Ontario, by allowing exploitation to expand to greater levels, is a distinct possibility that needs to be addressed. Although we have no evidence that elvers return to their parental freshwater residence, the chance that this may occur cannot be discounted entirely. For this reason, some level of emigration should always be permitted.

Table 1. Emigrating biomass (kg) of a cohort of 1000 eels under various scenarios of exploitation.

Exploitation Rate %	Exploitation: 0 at Age 4, Maximum Age 6	Exploitation: 0 at Age 4, Maximum Age 13	Exploitation: Knife-edge Age 11
0	1498.4	1498.4	1498.4
10	563.6	819.2	1004.7
20	201.3	450.7	682.6
30	66.6	247.5	466.2
40	19.8	135.0	318.1
50	5.1	72.7	215.6
60	1.0	38.4	144.1
70	0.1	19.8	93.8
80	0	9.9	58.3
90	0	4.7	33.1
100	0	2.1	15.1

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THE ESTABLISHMENT OF AN INTERNATIONAL EEL RESOURCE/INFORMATION CENTER

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The Institute for Anguilliform Research and Mariculture was founded in 1974, at the University of Bridgeport, as a means of coordinating faculty and graduate student research on the American eel (*Anguilla rostrata*). It quickly became obvious to all involved that an enormous curiosity about this enigmatic species existed. Requests for information about this fish and the research we were conducting came, not only from the scientific community, but also from writers requesting background information for stories, individuals interested in constructing and operating culture facilities, the curious public, various importers and exporters of fish and shellfish, and fishermen wanting to expand their interests by entering into the eel fishery. These information requests were not restricted to the United States, but were international in scope.

From the start, we considered answering these queries as an integral function of the Institute. Nevertheless, supplying much of the requested data oftimes proved difficult, because of problems in locating and obtaining it. Over the years, a great deal of this hard-to-find information has been amassed at the Institute to the point that the primitive filing system began to fail. It rapidly became evident that a more sophisticated system had to be incorporated if we were to continue to fulfill the information requests. Hence, the idea of a very specialized, computerized library/information center was born.

Justification for such a center was based on the following:

1. The increasing interests in the Anguilliformes, as evidenced by the number of requests we, as well as other organizations, were receiving on a more-or-less continual basis;

2. The large number of journal articles written about the eel during the past few years, as well as the voluminous amount of earlier literature on the anguilliformes necessitated use of a computer;

3. The fact that we already had more information on hand than could be obtained from three of the largest computerized search services now in existence;

4. In addition to being able to rapidly search the literature for interested parties, we also wanted to be able to provide hard copy of any and all papers cited in our literature searches, thereby conserving time and facilitating research.

During the summer of 1979, two grant proposals were written. One went to the Jessie Smith Noyes Foundation, the other to the Wahlstrom Foundation/Johnson Fund. Both were awarded to us in December of 1979.

The grants provided funds for the necessary hard and soft wares to construct a program that would search the eel literature on the basis of author(s), subject(s), species, stage and year of publication, as well as permitting us to insert special "Q" numbers for individual research at the Institute. They also provided for the hiring of computer programmers and an operator, as well as providing three graduate fellowships to hire students to find and xerox papers missing from our existing file. Funds to publish miscellaneous information, which we felt would assist and/or coordinate the eel fishery and eel research, were also provided.

In the past, we have published:

1. The Eel Cookbook: a "PR" gimmick to help general interest.

2. Occasional Papers: as with many laboratories, we had an abundance of extraneous data lying around - data that were not sufficient for journal acceptance but were sufficient to show trends and save time.

3. International Directory of Eel Workers: This was published in co-operation with Bill Rickards, Jack McCauley and John Foster of North Carolina Sea Grant Program. Inclusion in this directory was based upon literature citations, personal contacts, and queries sent to us.

We are presently working up the computer program. Our hope is to build a program which will permit us to systematically index our collection of information ranging from the eel's biology through its culture and fishery. Also included in the program will be categories for:

1. General works;
2. Bibliographies;
3. Popular literature on and lore of the eel;
4. Legislation pertaining to eels;
5. Laboratories, programs, and people involved with the eel; and
6. Marketing.

(Based on past experience, the last category will, undoubtedly, cause us a good deal of grief, but we are going to try.)

We realize that this is a major undertaking, but we feel that it is a worthwhile endeavour and one that is necessary in a world of expanding information and specialization. Our goal is to provide any interested individual with a complete up-to-date listing of the available information on any of the sixteen Anguilliform species. We also will be prepared to provide hard copy of any of the cited papers thereby, hopefully, facilitating extensive reviews of the eel literature. The projected on-line target date for this project is July, 1982. We would appreciate any assistance in this undertaking, particularly with regard to obtaining copies of reprints and in-house reports or in contacting individuals actively engaged in any apsect of "Anguilliphilia".

POLUHOWICH - DISCUSSION

1. Regarding the provision of information from the Centre, it was explained that there would be a charge for the service.

2. Reference was made to a European group that has compiled a list of 5700 papers on eels.

SEX OF ADULT AMERICAN EELS (*Anguilla rostrata*) COLLECTED AS ELVERS IN TWO DIFFERENT STREAMS ALONG THE EASTERN SHORE OF CANADA, AND RAISED IN THE SAME FRESHWATER POND IN ONTARIO

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INTRODUCTION

Several authors, including Bellini (1907), Tesch (1928), Gandolfi Hornyold (1929), Fidora (1951), D'Ancona (1951), and Kuhlmann (1975), studied the sex of adult European eels (*A. anguilla*), raised from juvenile stages under different conditions. The review of their findings is summarized by Bertin (1956), Sinha and Jones (1975), Tesch (1973, 1977), and Moriarty (1978).

No critical study on the sex of adult *A. rostrata*, raised from elvers, has been published.

The aim of the present study was threefold:

1. To establish some of the factors which could control the sex of adult American eels. Is the sex determined on fertilization (syngamic determination) or only much later, when the environment imposes one sex or another on them and can even cause a change of sex (metagamic determination)?

2. To obtain information on the rate of growth of elvers and adult eels in a new environment, and to learn whether it is practical to raise them in a pond for commercial purposes. (Usui 1974).

3. Using the knowledge of the age of the eels, accurate information is obtained on the number of so-called "winter zones" (translucent zones), formed on the otoliths after spending one or several winters in outdoors conditions in freshwater.

This study will present data regarding the first two aims, whereas the subject of the latter point already has been published by James and Vladykov (1967), Vladykov (1970) and Liew (1974).

Two groups of elvers were used in the present studies: one from the Digdeguash River, N.B. (from 1967 to 1970), and the other from Grande-Rivière Blanche, P.Q. (from 1970 to 1975). These two groups were transported to a freshwater pond at White Lake Fish Culture Station, Sharbot Lake, Ontario, where the studies took place (Table 1).

METHODS AND MATERIAL

In the present study, the lengths of elvers and eels refer to the total length, measured in a straight line from the tip of the lower jaw, mouth closed, to the posterior end of the middle caudal rays. Usually the measurements were made on specimens preserved in 4-5% formalin.

The other measurements were as follows: *i*, least bony interorbital width; and *O*, horizontal diameter of the eye. For further details, see Vladykov (1973).

COLLECTING AND TRANSPORT OF ELVERS

Elvers from the two localities were collected by the same methods: hand seine, dip net, and metallic seive.

We avoided the use of an electric shocker to exclude a possibility that an electric current could affect the differentiation of elver's gonads.

The number of elvers was established by weighing them, without water, in a nylon container.

When a desired number of elvers was collected, they were placed in a 113 L (80 cm x 80 cm x 60 cm) galvanized "splash tank". The water in the tank, up to 36 cm in depth, was oxygenated with pure oxygen from a cylinder and kept cool by dripping water from melting ice, held in a net above the tank.

Transportation was made by automobile (station wagon) during night hours. Later in the day, traffic was lighter on highways and cool night air helped to maintain a low temperature in the tank.

EXPERIMENT 1

Elvers from the Digdeguash River, which flows into Passamaquoddy Bay, approximately 16 km from St. Andrews, New Brunswick, were collected on July 26, 1967, below the Digdeguash Falls. The water temperatures varied from 18°C to 20°C.

The distance from Digdeguash River to White Lake pond in Ontario, about 1280 km, was covered in 16 hours. The water in the tank was changed and replaced with fresh water of a corresponding temperature once during transit.

Upon arriving at White Lake pond, early in the morning on July 27, the elvers were adjusted from the water temperature of 18°C in the tank to that of the pond (23°C) over a period of three hours. The elvers were then released at several places in the pond.

These elvers were partially pigmented and their stage of development correspond to VI A, according to Strubberg (1913).

An estimate of the number of elvers which were liberated in the White Lake pond on July 27, 1967, was 9000. Their length varied from 46 mm to 67 mm, with a mean of 56.6 mm. Their weight was between 0.07 g and 0.40 g, with a mean of 0.13 g. Thus, the estimate of biomass of elvers was equal to 1170 g.

A random sample of 257 elvers was preserved in 4-5% formalin for subsequent study, as a control in the experiment.

EXPERIMENT 2

Elvers were collected in the Grande-Rivière Blanche at St-Ulric, near Matane, P.Q. on June 17 and 24, 1970.

It took about 13 hours to go from the Grande-Rivière Blanche to White Lake pond, a distance of approximately 960 km.

On June 17, the temperature of Grande-Rivière Blanche was 19.4°C and in the morning of June 18, White Lake pond temperature was 21.5°C. The values for pH were 7.1 for the Grande-Rivière Blanche and 7.5 for the White Lake pond.

We collected approximately 3500 elvers on each trip. A random sample of 220 fish established that these elvers were less pigmented than those from New Brunswick, and length varied from 54 mm to 66 mm, with a mean of 60 mm. The mean weight was 0.22 g (variation was 0.18 gm - 0.50 g). Thus, the biomass of the estimated 7000 elvers was approximately 1540 g.

DESCRIPTION OF THE POND

The pond is on the grounds of the White Lake Fish Culture Station, of the Ontario Ministry of Natural Resources, located about 48 km west of Perth, Ontario, on Highway No. 7. It is a small, artificial pond about 1 acre (0.4 ha) in extent. It is oxbow shaped and has a mud bottom, over a rock formation. The maximum depth, close to the outlet, is about 2 m, with a mean overall depth of 1.5 m.

The pond is fed at the upper end by a pipe (5 m long and 23 cm in diameter) through which water runs by gravity from White Lake, a relatively large oligotrophic lake above the pond. A valve

Table 1. Number and Length of Adult Male and Female American Eels - originated from two different elver populations, after spending a corresponding time in White Land pond, Ontario.

	ELVERS						ADULT EELS				
		Length (mm)		Weight (g)		Est.	Winters Spent		No. of	Length (mm)	
	No.	Range	Mean	Range	Mean	Biomass	In Pond	Sex	Fish	Range	Mean
Experiment #1:	9000	46-67	56.6	0.07-0.40	0.13	1170 g	1	F	2	234-270	252.2
								M	13	235-326	289.2
(July 27, 1967-							2	F	26	198-478	291.7
May 18, 1970)								M	127	170-362	294.0
Elvers from							3	F	96	213-589-	314.2
Digdeguash								M	331	181-379	304.4
River, N.B.)											
								Experiment Completed			
Experiment #2:	7000	54-66	60.0	0.18-0.50	0.22	1540 g	1	F	5	230-458	330.4
								M	12	245-421	366.8
(June 18, 1970-							2	F	7	220-594	344.0
Sept. 18, 1975								M	5	241-380	313.0
Elvers from							3	F	17	237-392	288.6
Grande-Rivière								M	27	232-388	265.0
Blanche, P.Q.)							4	F	42	245-669	373.1
								M	28	242-415	335.8
							5	F	280	245-800	371.2
								M	75	232-421	335.5
								Experiment Completed			

on this pipe permits regulation of water flow into the pond from 0 to about 6750 litres per minute. The water flow during the experiment was maintained at about 1350 L/min.

Before entering the pipe, the lake water passes through two galvanized screens of 6 mm mesh. From the pipe, the water falls into an inflow cage (1.0 m x 1.0 m x 0.5 m) made of galvanized screen of 3 mm mesh and located about 60 cm below the pipe. This arrangement allows only small invertebrates and larval fish to enter the experimental pond. After leaving the inflow cage, the water flows about 7 m along a channel 60 cm wide, and drops into the pond in a 3 m fall.

The temperature of the water varied with the season. During the summer months, from the end of May to the end of September, temperatures averaged between 20°C and 24°C. In July and August, water temperatures were as high as 30°C in some shallow places, during the afternoon. Ice covered the pond from November to March.

During the warm season, the water pH remained close to 7.5.

The pond is surrounded mainly by deciduous trees. Aquatic vegetation was particularly abundant along the north-western shore, consisting almost exclusively of the flowering rush (*Butomus umbellatus*) and the cattail (*Typha*). In deeper holes, *Chara* and *Nitella* were present.

The pond was rich in different animal groups: Oligochaeta, Mollusca, Amphipoda (*Hyalalla azteca*), and different orders of aquatic Insecta. Among vertebrates present, minnows (*Hyborhynchus notatus*), darters (*Etheostoma exile*) and newts (*Notophthalmus viridescens*) should be mentioned, all of which were used as food by the eels.

To supplement natural food, the eels in the pond were fed with a mixture of ground beef heart and liver. During the warm season, about 1 kg of this mixture was put in the pond once every week. Approximately 40 kg per year were added.

The pond was completely drained 3 weeks prior to its preparation for each experimental elver transplant. The filling of the pond took approximately two days.

RESULTS

RATE OF GROWTH OF EELS IN THE POND:

During the two experiments, eels were collected from the pond with seines and baited traps several times a year; baited traps were more efficient. The number, sex, length and weight of adult eels[1] which typically were longer than 200 mm, were recorded. It should be noted that samples collected were not always representative.

Due to rather warm water in the pond, an abundance of food and apparently a limited population of young eels, the growth of survived fish was rather remarkable. Nevertheless, the rates of growth of adults originating from Digdeguash elvers and from Grande-Rivière Blanche elvers are somewhat different and they will be treated separately (Table 1).

DIGDEGUASH EELS:

An adult male, 281 mm in length and weighing 43 g, was taken in a baited trap kept in the pond from July 5 to 26, 1968. During the same year, from August 20 to September 6, three other adult males, ranging from 235 mm to 309 mm in length and weighing from 22.5 g to 40 g, were caught.

From September 20 to October 17, 1968, eleven more adult eels were taken. Seven of these were males, ranging in length from 263 mm to 326 mm, and weighing from 32.5 g to 52.5 g; two others were females, 234 mm and 270 mm in length, and 14 g and 27.5 g in weight.

The growth of the largest male, 326 mm and weighing 52.5 g, after only 14.5 months of sojourn in the pond, should be considered phenomenal. In contrast, native eels in New Brunswick's freshwater, such as Crecy Lake, only reach this length after 11-14 winters (Vladykov 1968). The length of the above male, in comparison with its initial size of 56.6 mm, represents a 6-fold increase; and its weight from 0.3 grams corresponds to an increase equal to 404 times.

In comparing the rate of growth of males and females, it became evident that males increase faster than females in length and weight at least after the first winter. For instance, in 1968, 13 males were all longer than two females. The range in length of the males was 235-326 mm, with a mean of 289 mm; the females were 234 and 270 mm in length, with a mean of 252 mm. During the second year, 1969, males averaged 294 mm, slightly longer than the females, which averaged 292 mm. Some individual females, however, showed very pronounced growth, reaching 478 mm in length. The maximum length of adult males from the Digdeguash was only 379 mm, whereas the maximum length of females was 589 mm. As we shall see in the next section, Grande-Rivière Blanche fish grow faster and reach a much larger size.

On May 18, 1970, the first experiment was terminated because all the eels reached adult size. During this experiment, a total of 662 adult eels were collected.

GRANDE-RIVIÈRE BLANCHE EELS:

Adult eels from the Quebec elvers showed an excellent rate of growth, even after the first winter spent in the pond: some females reached

[1] In the present article, the term "adult" eel is defined as a specimen at least 170 mm in length with its gonads sufficiently developed to permit sex determination.

a length from 440 mm to 458 mm; and males, 400-419 mm. Among these, one one-year old fish, measuring 421 mm in length and weighing 151 g, was the largest male in both experiments (Table 1). The maximum length reported for an *Anguilla rostrata* male was 503 mm, for a specimen from the Matamek River, Quebec (Dolan and Power 1977).

In subsequent years, the adult eels which remained in the pond continued to grow, especially the females. The largest females, originated from the Quebec elvers, collected in different years were as follows:

Year	Length (mm)	Weight (g)
1971	458	170
1972	594	454
1973	392	59
1974	669	613
1975	800	1003

On September 18, 1975, we terminated our experiments with eels from the Grande-Rivière Blanche elvers. The reason for this decision was the fact that all remaining eels had reached the adult stage. Altogether, 540 adult eels were collected.

An electric shocker was used for the final collection of eels in both experiments, and the pond was drained.

SEX OF EELS RAISED IN THE POND:

Determination of the sex of adult American eels raised in the pond was possible on specimens at least 170 mm in length. The testes or organs of Syrski are looped or lobed or festooned, as in the case of the European eel. The ovaries resemble "filled ribbons" (Bertin 1956; Sinha and Jones 1975; Tesch 1977; Moriarty 1978).

In the beginning, we examined the gonads of 25 adult eels, macroscopically, and checked our determination by histological methods. The sex of only one specimen was not properly determined macroscopically. Several adult specimens, especially ones during the first and second year in the pond, had gonads that were in an undifferentiated state.

The aim of our study was to find if there is a definite trend in sex differentiation of adult eels in the new environment. For this reason, we did not study every specimen histologically. We considered that macroscopical examination would be sufficient, and any specimen with gonads that were not clearly differentiated was disregarded. Moreover, the number of individuals with undifferentiated gonads, indicated by a question mark (?), was not more than 10 percent of the total.

The diameter of the eye (*O/i%*) of males, especially those advanced in maturity, is much larger than in females (Vladykov 1973). Moreover, maturing males display a bronze-metallic shine, while females of a corresponding size are yellow or green in colour.

Lastly, the males could easily be distinguished from females by their smaller size. For *A. rostrata* males, the greatest length was 421 mm and weight 150.5 g. This specimen originated from Grande-Rivière Blanche elvers. The average length of adult *A. rostrata* females, which support commercial fisheries in Quebec and Ontario, is 910 mm and 1.59 kg (Vladykov 1955, 1966, 1970)

Although elvers from the Digdeguash River and those from Grande-Rivière Blanche were kept under the same environmental conditions in the White Lake pond, the sex composition of adult eels was very different:

ADULT EELS

	Digdeguash River		Grande-Rivière Blanche	
	N	%	N	%
Females	124	18.7	351	65.0
Males	471	71.2	147	27.2
?	67	10.1	42	7.8
Total	662	100.0	540	100.0

DISCUSSION

A previous study by Vladykov (1966) revealed that the size of *A. rostrata* elvers along the western Atlantic shore increased from south to north. For instance, the average length of elvers in Florida is 52 mm while in Nova Scotia and Quebec waters, it is at least 58 mm. The same author postulated that smaller elvers produce mostly males and longer ones metamorphose into females. The same conclusion, for *A. anguilla*, was reached by Bellini (1907), who divided elvers from the Comacchio area, by their length, into three categories: 46-61 mm, 63-73 mm, and 78-84 mm. Each group was reared in a separate reservoir. The results of his experiments were that the small elvers produced males only and the big elvers, only females. The intermediate group apparently contained both males and females.

Several authors, such as Tesch (1928), Gandolfi Hornyold (1929) and Kuhlmann (1975), to mention a few, have studied the sex of adult European eels raised not from elvers but from juvenile stages. Since they did not definitely know the sex of the younger fish, their conclusions on the sex ratio among adult eels in different samples are not comparable.

SUMMARY

On the basis of herewith presented data, the following conclusions can be drawn.

1. The present paper has a certain distinction

as a unique study dealing with observations on growth and sex differentiation of *A. rostrata* elvers from two different populations, but reared in the same pond under identical environmental conditions.

2. Collection, with a small seine and a hand dip net, and transport of elvers over considerable distances (over 1000 km), do not present any difficulty. Mortality of elvers during transport, even in a small "splash tank" is practically non-existent.

3. The rate of growth of elvers and adult eels, in a freshwater pond on the grounds of the White Lake Fish Culture Station, in Ontario, is very rapid at the initial elver density of 3000-4000 per hectare (7000-9000 per acre).

4. Elvers collected from two different streams along the eastern shore of Canada and raised in the same freshwater pond in Ontario (but in different years) did not manifest the same rate of growth.

5. Among adult eels from the Digdeguash River, males were represented by 71.2% and females by only 18.7%. In the Grande-Riviere Blanche sample, the situation was reversed: males represented only 27.2% and females 65.0%.

6. Our two experiments on the sexuality of American eels, conducted in the same pond under essentially identical conditions, produced very different results with respect to the sex ratio. Thus, it is clearly demonstrated that the sex of *A. rostrata* is determined on fertilization (syngamic determination) and not influenced by the environment.

ACKNOWLEDGEMENTS

The present study is dedicated to the Ontario Ministry of Natural Resources for their gracious permission to utilize one of their freshwater ponds on the grounds of the White Lake Fish Culture Station, Sharbot Lake. This pond was utilized for the duration of eight years (July 27, 1967-- September 18, 1975).

The technical assistance, supervision, taking of water temperatures, and feeding of eels was most kindly and generously provided by Keith Steele and his resident staff.

D. T. James, formerly a graduate student of the Department of Biology, University of Ottawa, collected the elvers in the Digdeguash River, transported them to the White Lake pond and took periodic samples of eels from the pond.

Germain Labrecque, Ministry of Fish and Game, Quebec, guided us and helped collect elvers in Grande-Rivière Blanche.

The University of Ottawa professors, James C. Fenwick and Thomas W. Moon read the manuscript and offered valuable suggestions; they also participated in collecting eels in the pond at the end of both experiments.

The authors have the pleasure to express their most sincere thanks to all the above mentioned institutions and individuals who contributed their effort to the realization of our experimental project.

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EEL MARKETING

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After a brief introduction, Mr. Robberecht gave a review of his experience and background in the eel fishing industry. It ranged from fishing in Ontario and New Brunswick, to buying and shipping eels from the Maritimes and the State of Maine to Europe by sea. Later, using a DC7 and buying eels in the United States, he flew them to Europe from Richmond, Virginia. Following this experience, Mr. Robberecht fished eels in Chesapeake Bay rivers, principally in the Potomac River, where he has taken approximately 750,000 each year since 1963. After some costly experiences, he stopped flying eels to Europe in his own plane. He now flies eels to Europe by commercial airlines.

Mr. Robberecht at one point entered the elver fishing and export business. His principal market was in Japan, where they were involved in a major eel culture operation. Later the Japanese buyers would buy only glass eels. Mr. Robberecht was able to catch these up the Frederick River, 210 kilometers (130 miles) upstream from the river mouth on Chesapeake Bay. Business arrangements became difficult and his elver operation broke down.

The speaker briefly reviewed the Japanese culture operation and how they grow eels in "hot houses" in 22°C (72°F) water. They can grow elvers to marketable eel size in one year. Mr. Robberecht indicated that elvers moved from one country to another do not necessarily grow well. In some instances, introduced elvers do very poorly.

Mr. Robberecht's present eel culture project, which is operated in conjunction with his eel export business, involves 10 one-acre ponds where he raises small eels that cannot be sold in Europe. These eels, which are fed on a diet of ground fish, reach a marketable size.

Mr. Robberecht stated that the biggest eels are not the most valuable on the European market; they are too expensive to sell.

He expressed his views on various mesh sizes for hoop nets, traps, etc.

Mr. Robberecht concluded by saying that we should not harvest elvers for export as we will ultimately destroy our commercial eel fisheries.

PROPOSALS FOR THE MANAGEMENT OF NORTH AMERICAN EEL STOCKS

A panel of three representatives was asked to consider the Conference presentations and discussions and to give their views of what was learned, relative to the meeting objectives as outlined, and the eel fishery management situation in their particular regions. Delegates were chosen from different regions and jurisdictions with the thought that this would tend to give a broader view of the direction the meeting took and the conclusions that might have been reached.

MARITIMES

B. M. Jessop
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Maritimes Region eel management is now in the formative stage demonstrated by the Saint John River eel fishery policy.

Eel "management" has been by minimal regulation by fishery officer evaluation.

Changing times and circumstances indicate a need to give the eel resource more attention.

The requirements for effective eel fishery management should follow the same pattern as that of other fisheries, i.e. formulation of a policy, provision of a mechanism for continual review and revision of fishery regulations including recommendations of catch quotas and inputs of biological and other information.

Mr. Jessop indicated that at the present time, there appears to be no need for an inter-regional approach to management, since there is no evidence that the return, destruction or distribution of elvers is in any way affected by the present level of harvesting in a particular region. The speaker indicated that, if it were possible, there is no apparent reason why every silver eel leaving Maritime streams should not be harvested. He suggested that for the present, at least, local management seems preferable to any inter-regional arrangement. He added that, for the most part, eel fisheries are local in nature with large areas lightly fished or unfished. General observations indicate that there is no evidence that the supply of elvers has diminished, but the matter has not been investigated scientifically.

Mr. Jessop proposed that the potential benefits of inter-agency coordination would probably best be realized from the exchange of biological and local information, rather than the establishment of an inter-regional management plan.

He concluded by stating that a forum for information exchange would benefit the Maritimes and might stimulate the development of a regional research program. It was suggested that an annual or biennial meeting, perhaps in association with meetings of the American Fisheries Society, would be worth considering.

ONTARIO

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The speaker opened her remarks stating that she disagreed with Mr. B. M. Jessop when he expressed little concern for "over-harvest" of eels. Ms. Kolenosky referred to basic biological principles which deal with protection of breeding stocks. She proposed that fishing pressure is not the only stress on fish populations and that "these other factors", by compounding the fishing effect, may ultimately result in the demise of a population. She added that it is her belief that there is a potential for over-harvesting North American eel stocks. The speaker went on to present and discuss four assumptions:

1. There is no stock recruitment relationship. Ms. Kolenosky expressed the doubt that anyone has sufficient data on any species to know if such a relationship exists.

2. There are many rivers that can produce all the fish we need and all the elvers we need. The speaker raised the question of how long this situation would last if the demand for eels increased and fishing technology for eel harvesting improved. She added that there are unknown factors such as acid rain, its effect on the Precambrian Shield area, and the effect this will have on eel production levels in the rivers of Ontario, Quebec, Labrador, the Maritimes and New York.

3. We cannot catch all the silver eels. The speaker indicated that this is a logical assumption with the type of gear now being used. Ms. Kolenosky posed the question of what amount of escapment is necessary, in

view of the fact that there are probably many other obstacles that face eel migrants before they reach their spawning areas in the Sargasso Sea.

4. We have random recruitment and there are no discrete stocks.
The speaker raised the question regarding eel stocks: Are the eels of Lake Ontario one stock? Or, are the eels of Lake Ontario and the St. Lawrence one stock? Or, are the eels of the entire eastern seaboard one stock? She offered an answer to the question by stating that it is unlikely that anyone really knows.

Ms. Kolenosky referred to points raised by Dr. C. L. Deelder regarding the future acceptability of eels in the European market, i.e., the contaminant level in eels that Europeans will accept and the production of high quality "cultured eels". She proposed the transfer of elvers, from the Cornwall (Ontario) eel ladder to low contaminant level waters, for rearing. These contaminant-free eels would be suitable for both European and North American markets.

Ms. Kolenosky raised a number of other points related to Lake Ontario eels, such as the effect of the Moses-Saunders turbines on downstream migrant eels, and the need for the development of a uniform and effective aging technique for eels.

Ms. Kolenosky agreed with Mr. B. M. Jessop that there is a real need for a forum, for management and biological information exchange. She added that the "committee" should meet every two or three years, but with a continuous exchange of information. She concluded that there should be a coordinator to keep the group alive and that the North American group should maintain an exchange of ideas with the ICES/EIFAC working group.

NEW YORK

W. Pearce
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The speaker stated that most specific items had been covered by the two previous panel members. He spoke on general points related to the eel.

He stated that there are two universal concerns for eel populations: first, that there is great interest in protecting an adaptable animal that has survived such a variety of obstacles; and second, that the eel is almost universally considered a commercial species, which is quite unique among "fresh water" species. He added that it is important, therefore, to develop effective ways of harvesting, marketing and managing eel stocks.

Mr. W. Pearce referred to the interest generated by the Conference and added that it appears that the only existing coordination efforts in the eel research and management fields are at the University of Bridgeport and in Europe. Referring to Dr. C. Moriarty's presentation, he mentioned a point made regarding the importance of keeping research simple. The speaker commented on the importance of international research information through the use of a data bank.

The speaker expressed similar concerns to those of the previous speaker when he stressed the danger of over-harvest of fish stocks and the ultimate reduction and elimination of some stocks. He continued by commenting on the importance of coordination and exchange of information, which points up the need for an organization to keep up the interest in the eel that has been demonstrated at the Conference. Mr. W. Pearce referred to the success of work initiated 25 years ago by the Great Lakes Fishery Commission to implement a sea lamprey control program.

The speaker referred to the danger of contaminants and to some of the less obvious but lethal effects some of these have on fish stocks, for example, the reduction or elimination of spawning success. This phenomenon has resulted in the elimination of some New York lake trout populations.

Mr. W. Pearce admitted that, although there appears to be no proof, he feels there must be some "homing instinct" in eels.

CHAIRMAN'S REMARKS

Chairman, Mr. A. H. Lawrie, added a few remarks at the conclusion of the panel presentations.

Mr. Lawrie raised the question of what is meant by "management", adding that in the Great Lakes, stocks of fish have been progressively eliminated through the use of selective gear which has essentially reduced spawning stocks to critical levels, after which recruitment fails. He proposed that protection from this type of situation should be a management consideration, but the word "overfishing" is used to describe it. He suggested that this is not the traditional meaning of the word "overfishing" and that what is really being sought is a method to adjust the system and manage it in order to maximize the yield of fish. He indicated that, at first, we may make mistakes by laying serious constraints on the fishermen, both commercial and sport, taking away opportunities that they could have. The second step, which has not been referred to often in the Great Lakes, is the opportunity to provide the fishermen with a substitute for, or restoration of, what has been taken away from them. The Chairman, therefore, suggested that if we are going to talk about the purposes of managing eel stocks, we had better be clear on what it is we are seeking to do.

The Chairman concluded by indicating that the panel proposed that a group similar to the ICES/EIFAC group is needed in North America.

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